Chapter 19. Salt and Salinity Management — Table of Contents

Tables

Figures

Boxes

Chapter 19. Salt and Salinity Management

Unlike the crisis scenarios California routinely prepares for, chronic water quality problems like increasing salinity do not trigger overnight evacuations or mobilize teams of emergency personnel. Salinity generally shows up in localized areas, expands slowly, and produces incremental rather than event-based effects. Salinity impacts can be measured as yearly reduction of crop production and farmable land across an impacted region, lost jobs, higher utility rates, reduction of community growth potential, loss of habitat, premature corrosion of equipment, and lost opportunities. Salinity issues are rarely considered newsworthy until the impacts have already occurred.

Managing salt today can avoid significant cost increases. For one portion of California, a State Water Resources Control Board study found that Central Valley salinity accumulations, if unmanaged, are projected to cause a loss of $2.167 billion in California's value of goods and services produced by 2030 (Howitt et al. 2009). Income is expected to decline by $941 million, employment by 29,270 jobs, and population by 39,440 due to the increase in commercial operating expenses incurred by water supplies that have higher salinity concentrations. The study examined the impact to irrigated agriculture, confined animal operations, food processors, and residential water users. Potential benefits of implementing a salinity management program just in the Central Valley are estimated to be $10 billion by 2030. There have been similar studies conducted in other parts of the state and nation. The Southern California Salinity Coalition was formed in 2002 to address the critical need to remove salt from water supplies and to preserve water resources in California (see www.socalsalinity.org/index.htm). The Multi-State Salinity Coalition addresses similar issues (see www.multi-statesalinitycoalition.com). Both groups indicate that proactive salt management through combinations of source control, treatment, storage, export, real time management with dilution and recycling, is economically beneficial.

Salinity management not only reduces salt loads that impact a region, it is also a key component of securing, maintaining, and recovering usable water supplies. Salt is ubiquitous throughout the environment and it is a conservative constituent meaning it is never destroyed, just concentrated or diluted and transported. It also means that the concentration and loads of salt within any given area will have direct impacts on most of the resource management strategies in place or currently being developed (Figure 19-1).

PLACEHOLDER Figure 19-1 Relationship between Salt and Salinity Management and Other State Water Plan Resource Management Strategies

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

While there is no single solution that can be implemented to resolve increasing salinity, incremental management steps, such as those outlined in the Recommendations Section, can move the state forward to address this growing threat to the California economy.

Background

Salts may be defined as materials that "originate from dissolution or weathering of the rocks and soil, including dissolution of lime, gypsum, and other slowly dissolved soil minerals" (Ayers and Westcot 1994). "Salinity" describes a condition where dissolved minerals are present from either natural or anthropogenic origin and carry an electrical charge (ions). In water, salinity is usually measured as electrical conductivity (EC) or total dissolved solids (TDS) and the major ionic substances found in water are calcium, magnesium, sodium, potassium, bicarbonate, sulfate, chloride, and nitrate. Both salinity measurement methods give an indication of salt concentrations in water or soils, but since mineral ions do not all carry the same electrical charge and organic dissolved solids can skew TDS readings, these measurement methods must either identify the sample location (e.g., the sample was collected in a tidal estuary, at a municipal outfall or from a domestic supply well) or be used in tandem with additional analyses.

Salt is present to some degree in all natural water supplies because soluble salts in rocks and soil begin to dissolve as soon as water reaches them. Since salts are conservative, any water use and reuse increases salinity as each use subjects the water to evaporation. If reused water passes through soil, additional dissolved salts will be picked up. The continued concentration of salt is a major element of any recycled water project as noted in the State Water Resources Control Board Recycled Water Policy (Resolution 2009-0011) and discussed in Chapter 12, Municipal Recycled Water in this volume.

Salinity problems in California, as in other parts of the world, tend to have both natural and human causes. California's natural geology, geography, and hydrology create different salinity concerns in different parts of the state. Coastal areas are subject to natural fluctuations in seawater intrusion on local aquifers. Centralized, closed basins (e.g., the Tulare Lake basin) are natural salt sinks where water moves downhill to the center of the basin, evapoconcentrates and impacts both surface and groundwater. In addition, many of California's most productive soils originate from ocean sediments that are naturally high in salts. Surface water dissolves that salt and either transports it downstream or it infiltrates through the soil column to add additional salt to the groundwater.

Human activities have changed both the rate and distribution of salt accumulation in California. Increasing seawater intrusion in coastal aquifers has been triggered by local groundwater pumping that removes more fresh water than is recharged into an aquifer. Climate change and the projected sea level rise associated with it will make this problem worse. Salts are often added to soil or water intentionally as fertilizers or soil amendments or to assist in industrial, domestic, or other processes (e.g., food processing and water softening). In the Owens Valley and other arid areas of California, diversion or lack of local water supplies leaves saline soils exposed to wind and dust storms may transport salt over great distances before deposition.

Salts may also enter a watershed through inadvertent means. These might be thought of as "unintentional salts," where human action aimed at some other purpose results in salts being added to the watershed. An example is the use of home water softeners that discharge salts into the sanitary sewer system increasing the salt load to both the wastewater treatment plant and the watershed. Many homeowners may be unaware of this.

California's extensively modified natural water systems and constructed conveyance channels supply large cities, small communities, farms, and wetlands with water, but each water delivery carries a salt load of varying degrees depending on the source water. When water is consumed through use, the majority of its salt load remains at or near the site of consumption. One example is imported Colorado River water used in Southern California. The Imperial Irrigation District reported that approximately one ton of salt is contained in each acre-foot (af) of imported Colorado River water (Imperial Irrigation District 2010). In 2011 alone, the importation added approximately 4.3 million tons of salt to Southern California (3.6 million tons of salt to the Colorado River Hydrologic Region and 0.7 million tons of salt to the South Coast Hydrologic Region) based on water use from the Colorado River (U.S. Bureau of Reclamation 2012). Another example is the state and federal systems designed to capture water exiting the Central Valley through the Sacramento-San Joaquin River Delta (Delta). This water provides replacement irrigation supplies for water diverted from the San Joaquin River basin, additional irrigation supplies for the Tulare Lake basin, and municipal supplies for the Central Coast and Southern California. In the San Joaquin Valley, there is not enough salt exiting the basin through the area's rivers and streams to offset the imported and recirculated salts. Because the Tulare Lake basin is a closed basin, it captures and retains all imported salt. Figure 19-2, using Department of Water Resources (DWR) and U.S. Bureau of Reclamation (USBR) water delivery data through 2010, depicts the mean annual salt loads conveyed to and from the Delta through the major river systems of the Central Valley.

PLACEHOLDER Figure 19-2 Salt Load (Mean of Annual Averages from 1959 to 2012)

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

New Delta Influence: Tidal Action, Delta Levees, New Conveyance Facilities, and Water Salinity

Tidal forces from the Pacific Ocean move into the San Francisco Bay and collide with the Delta outflow from the Sacramento and San Joaquin rivers, which creates a long and gradual salinity gradient. The position of this gradient depends upon the tidal cycle and the flow of freshwater through the Delta. Before the major dams were built, the upper edge of this salinity gradient moved deep into the Delta during drier years. The salinity reached as far as Stockton on the San Joaquin River and beyond Courtland on the Sacramento River. Today, Shasta, Folsom, Oroville, and New Melones Reservoirs help control salinity intrusion by providing fresh water releases during the drier parts of the year.

Delta waterways are a major geographical feature of the of California's water resources system because they receive runoff from more than 40 percent of the state's land area and pumping facilities convey this fresh water from the north to the south. Due to continuous land subsidence, the western Delta islands need protection from flooding by levees. Levees also help to protect water-export facilities in the southern Delta from saltwater intrusion by displacing water and maintaining the salinity balance.

If the fragile Delta levee system fails and the islands become inundated with saline water, the water available to the pumping facilities near the Clifton Court Forebay may become too saline to use or can cause major short-term water quality problems. For instance, during one incident an island was flooded under low-flow conditions and at the Contra Costa Canal intake chloride levels reached 440 parts per million (ppm), which is well above the California secondary standard for drinking water of 250 ppm.

In addition, climate change projections indicate that the Pacific Ocean level along the California coast will rise by 14 inches on average by 2050 and as much as 55 inches by 2100 (State of California Sea-Level Rise Task Force 2010). This change will likely increase tidal flows and therefore increase salinity levels in inland Delta waterways. Because much of the water used in the state passes through the Delta, managed outflows will have to be increased to repel intruding seawater and maintain water quality standards.

To overcome these and other risks, the State Water Project (SWP) and the Central Valley Project (CVP), under the umbrella of the Bay Delta Conservation Plan goal of improving the reliability of delivery of water supplies, propose constructing a distinct water delivery system to carry Delta freshwater flows. Proposed infrastructure alternatives for this new system would move water around, through, or under the Delta to convey water from the Sacramento River near Hood to the major water distribution facilities in the South Delta. From 1999 to 2010, the average salinity level at the Sacramento River near Hood was 92 milligrams per liter (mg/L) TDS. By comparison, salinity levels south of the Delta at the SWP's Banks Pumping Plant and at the Delta Mendota Canal were 218 mg/L and 275 mg/L TDS, respectively. This is more than double the salinity level north of the Delta. Any of the proposed conveyance facilities would have a major impact in reducing salinity loads, described below, with an estimated salinity load reduction near 1 million tons of salt per year.

State water contractors conclude that the new system would reduce salinity loads in the San Joaquin Valley, facilitate Metropolitan Water District's water supply blending goals with the saltier Colorado River water, and improve the quality of water used for groundwater replenishment and recycling. They estimate a benefit of $95 million per year in regional water quality savings. The benefits for the CVP contractors would be significant as well, since salinity levels tend to be higher at the South Delta federal intakes than anticipated using the new system. Figure 19-3 shows a comparison of salt loads delivered by the proposed Delta tunnel conveyance facilities with the existing South Delta state and federal water delivery facilities.

PLACEHOLDER Figure 19-3 Salt Loads Comparison: Existing South Delta State and Federal Pumping Plants Intakes vs. Proposed Delta Conveyance Tunnels

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While such reductions could alleviate a portion of the salt loading occurring in other basins, as was recognized during the development of the federal CVP and the SWP, continued salt imports combined with consumptive use in closed basins, such as the Tulare Lake basin, requires development of an out-of-basin conveyance to reach sustainability.

Beneficial Use Impacts

Most salts provide some benefit to living organisms when present in low concentrations. However, salinity very quickly becomes a problem when consumptive use and evaporation concentrate salts to levels that adversely impact beneficial uses.

In California, waters of the state (surface and groundwater) are designated as having one or more beneficial uses such as municipal supply, agricultural irrigation, aquatic life, and recreation. Most designations are adopted by Regional Water Quality Control Boards, which have the responsibility of protecting the uses within their region's boundaries. In addition, the State Water Resources Control Board (SWRCB) Resolution No. 88-63 (State Water Resources Control Board 1988) directed each Regional Water Quality Control Board to designate surface water and groundwater in the region as being potentially suitable for drinking water unless certain existing conditions apply. A water body is exempted from the designation if, for example, salinity is 5000 µS/cm or more and where "it is not reasonably expected by Regional Boards to supply a public water system." The three water uses that salinity generally impacts first are agricultural production (AGR), drinking water (MUN), and industrial processing (PRO) as shown in Table 19-1. Regional Water Quality Control Boards develop regulatory thresholds to determine if there are actions needed to protect a use. The thresholds are developed by taking into consideration established thresholds, background conditions, and existing and potential beneficial uses. Figure 19-4, developed by the U.S. Department of Agriculture (USDA) Natural Resource Conservation Service, depicts areas of soils with high salinity and/or sodicity using common thresholds where most crops are negatively impacted. Under current management, these impacted areas are anticipated to continue expanding. Note that the coverage is not complete throughout the Mojave Desert Region so it does not represent some areas suspected to have high salinity and/or sodicity.

PLACEHOLDER Table 19-1 Example of Impacts of Salinity on Three Beneficial Uses

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

PLACEHOLDER Figure 19-4 Areas of California Soils with High Salinity and/or Sodicity (USDA)

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

While AGR, MUN, and PRO are the beneficial uses most sensitive to excess salinity, there are also potential impacts on environmental uses. Habitat can be impaired, breeding areas can become less functional, and in extreme cases, organisms can succumb to salt toxicosis. It is beyond the scope of this general salinity discussion to address the impacts of specific ions in great depth, but certain individual ions can limit attaining beneficial use even when the general salinity level may not otherwise pose a problem. Groundwater recharge can be impacted when the receiving aquifer cannot accept the saline water without violating California's anti-degradation policy (State Water Resources Control Board 1968). Groundwater overdraft also poses a salinity problem in areas like Madera County where the excessive drawdown of fresh water leaves the aquifer vulnerable to intrusion from high salinity shallow groundwater in neighboring areas, threatening the basin's supply of usable water for drinking and irrigation. The Salton Sea Authority reports that salinity is a growing problem in this water body due, to a large extent, the continued conservation efforts that will dramatically reduce inflows. Although the reduction in flow reduces salt loads, the reduction also decreases the total volume, increasing salt concentrations and exposing shoreline. If these trends continue, there will be an increasing negative impact on beneficial uses including fish reproduction, commercial fishing, and recreation (Salton Sea Authority 2009).

Beneficial use discussions sometimes leave the impression that water supports one set of uses and then becomes waste. In California, as in most arid states, this is rarely true. Many California communities routinely use water that has previously been diverted multiple times for irrigation or municipal use and returned to a water body. There is often a high demand for recycled water for landscape use, but salt concentrations must be managed to protect the beneficial use (in this case, irrigation and groundwater recharge) or this potential water supply is lost. High salinity in delivered water is a major obstacle for developing cost-effective recycled water of acceptable quality.

Salt and Salinity Management in California

Over the centuries, salts have been poorly managed in all parts of the globe where irrigation has been used. Mismanagement has often been attributable to a poor understanding of the dynamics of salt movement. Displaced salt can accumulate over time to salinize soils and aquifers, in much the same way that sweeping a room displaces dust. Unless sufficient dust is picked up and taken out of the room at some point, it will continue to accumulate and redisperse, ultimately making the room unfit for use. Most irrigation practices tend to have this effect on agricultural land unless steps are taken to ensure that salt is not just displaced within a basin but is sustainably managed, including concentrating and exporting it if needed.

Lack of knowledge is not the only cause of salt mismanagement. In his book, *Collapse*, Jared Diamond describes how Australia's current salinity problems can be traced back to decisions to mine the continent of its resources rather than harvest resources sustainably and preserve the land for future generations (Diamond 2005). Today's Australians are living with that legacy and attempting to reverse the damage caused by more than a century of salt mismanagement, in addition to facing unprecedented drought conditions. Californians will avoid this fate only by making sustainable salt management a priority today.

Salt management must address two major issues. These are 1) short-term impacts from elevated concentrations and 2) long-term impacts from displacing large loads of salt into areas where they can accumulate — the soil profile and groundwater. Historically, strategies to deal with excess salinity have included source control, dilution, and displacement. More recent strategies are treatment, storage, export, real-time management and recycling, and a long-term strategy is adaptation. These different strategies are described in more detail below.

Source Control

Source control can be defined as a broad array of measures to use water more efficiently and to manage it in a way that reduces the magnitude and adverse effects of salinity. Most regulatory activities have focused first on source control. The controls may be site- or industry-specific (e.g., improvement and/or removal of water softeners, replacing mixtures of chemicals in industry processes, good housekeeping and internal storage of industrial chemicals to avoid spills) or may have a broader base such as 1) minimizing soil amendments used in crop production, 2) using an alternate water source to lower initial concentrations, and 3) reusing the same volume of water to decrease overall loads within a given region. Source control, like other management options, walks a delicate balance between managing the salt concentrations and loads. Box 19-1, "Case Study 1: Santa Clarita Valley Automatic Water Softener Project," provides an example of measureable source control success.

PLACEHOLDER Box 19-1 Case Study 1: Santa Clarita Valley Automatic Water Softener Project

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

Dilution and Displacement

Agricultural operations typically displace salts suspended in the soil by applying more irrigation water than the crop is able to use in order to flush salts out of the root zone and to relocate them to a lower part of the soil profile below the root zone or to groundwater (the leaching fraction). However, salt may wick upwards again if evaporation exceeds recharge. Salt concentrations in surface water can be decreased by dilution with lower salinity water. Conversely, the salt load transported in water can increase with dilution since dilution water generally carries some salt load as well. A high volume of low salinity water can move significant amounts of salt to other areas, making it also worthwhile to investigate whether management of salinity is appropriate in areas where salt problems do not exist yet. All of these factors and more must be taken into account when developing strategies. Dilution and displacement strategies must be coupled with long-range water, ecosystem, and land resource management planning so that opportunities to move closer to a sustainable salt balance in California's hydrologic basins are not missed.

Opportunities could include 1) taking advantage of wet water years to transport salts back to the ocean and to store water for future use as dilution flow or to prevent saline water intrusion, 2) leveraging funding availability where a community can use both public and private monies to upgrade infrastructure to improve salt management, and 3) developing new businesses such as energy production (using saline water for cooling, sending high salt, high nitrate dairy waste to digesters for methane production, collecting salt to capture energy in solar ponds). All of these can also centralize salt collection as discussed below.

Treatment

Recent salt management strategies have included treatment using membrane or distillation technologies. Treatment, however, generates a highly saline solid or liquid waste product that must be managed appropriately and also has a significant energy demand. Treatment technologies are used sparingly in much of the state because energy and waste disposal costs can often exceed the economic value of the fresh water being produced. There have been some pilot studies of combined energy generation/salt separation methodologies. Given the heightened focus in California on energy and greenhouse gas (GHG) reduction, these methodologies may gain more attention as a possible salt management strategy. Because mineral salts are not all the same, salt treatment technologies vary in effectiveness and cost for any given situation. For example, desalination of high sulfate groundwater requires a different approach than desalination of high sodium seawater. Seawater desalination is a relatively mature technology, but additional research and development is needed to make brackish water desalination cost-effective in a broader range of settings. Current technology is generally cost-prohibitive for use in removing salts from wastewater treatment plant discharges due to the high costs of the reverse osmosis desalinization process and disposal of the byproduct brine concentrate. Some exceptions include the Orange County Groundwater Replenishment System, which desalinates local wastewater treatment plant effluent and injects the product water into the groundwater to prevent seawater intrusion into the local groundwater aquifer and for later extraction for water supply. In the Orange County case, the brine water component is discharged into an existing ocean outfall. For a broader discussion of desalination and recycled water, see Chapter 10, "Desalination — Brackish Water and Seawater," and Chapter 12, "Municipal Recycled Water," in this volume.

[NOTE: Additional content to be provided by author describing the connection between Municipal Recycled Water RMS and Salt & Salinity Management RMS. Jose Alarcon 11/9/12.]

Collection and Storage

Salt collection and storage is another strategy that is often used in inland areas and in most cases is required for the waste stream generated in treatment processes. Collection and storage may not be a sustainable solution if the collection area could release the salt to groundwater or if a severe storm event could potentially re-disburse the salt outside of the collection area. Evaporation basins, such as the one shown in the photo, raise other environmental issues as well. A collection and storage strategy is expensive and requires a large amount of land and appropriate mitigation for the impacts to wildlife. Although other constituents may also complicate collection strategies, there are success stories. Boxes 19-2 and 19-3 that describe Case Studies 2 and 3, respectively, are examples of farm-level salt management. Ideally, collected salt could be marketed as an industrial product. There have been some preliminary studies, but it is not generally considered feasible to market salt harvested as a byproduct of drainage management. As an example, industrial salt users require a purer and less seasonally variable product than can be produced from most saline drainage collection facilities. There has also been some discussion of harvesting and marketing other materials (selenium, boron) from certain salty waste streams to make the waste less of an environmental problem, but this strategy would have the same issues of cost-effectiveness, purity, and seasonal variability. However, markets change and it may be worthwhile to pursue these options in the future. Salt treatment, including brackish water at $500 to $1,200/af and seawater desalination at $1,000 to $2,500/af, will continue to be an expensive, but an increasingly attractive alternative for communities as California continues to grow and demand for water increases (cost information from Desalination Resource Management Strategy).

[NOTE: Cost information will be updated when RMS Chapter 10, Desalination – Brackish Water and Seawater is available.]

PLACEHOLDER Box 19-2 Case Study 2: Integrated On-Farm Drainage Management — A Farm-Level Solution to Problem Salinity

PLACEHOLDER Box 19-3 Case Study 3: San Joaquin River Water Quality Improvement Project — A Regional Solution to Problem Salinity

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Export

In many regions of the state, isolation and storage of salts is providing only a short-term management solution due to the inability to isolate fully the ever-growing salt mass that accumulates over time. More areas are looking at export opportunities such as brine lines to move salt to the ocean — a natural process that was interrupted in some basins by hydrologic modification. One successful brine line was developed in the Santa Ana watershed through a stakeholder process spearheaded by the Santa Ana Watershed Project Authority (SAWPA). The system is the primary method of long-term salt balance for the basin as discussed in Box 19-4, containing Case Study 4. Several coastal wastewater treatment plants also have ocean outfalls. East Bay Municipal Utility District has a local brine disposal facility that receives trucked brine with the capacity to develop regional brine lines further. The local systems primarily serve local or regional industry producing high salinity wastewaters, which may not require or be suitable for traditional municipal wastewater treatment. Agencies and groups in the Calleguas Creek watershed are pursuing a variety of options in their salt management plan that begin at source control and lead to large scale desalting and disposal including a brine line and ocean outfall. The SWRCB is in the process of amending the Water Quality Control Plans for Ocean Waters and Enclosed Bays and Estuaries to address desalination facilities and brine disposal.

PLACEHOLDER Box 19-4 Case Study 4: Salt Management in the Santa Ana Watershed Requires Regional Salt Disposal Options

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Real-time Salinity Management

Real-time salinity management is a strategy for meeting downstream salinity objectives by making use of a river's assimilative capacity and improving coordination of upstream constituent loading from point and non-point sources with dilution flows (Quinn and Karkoski 1998). The concept is being evaluated as a management alternative in the San Joaquin River basin to ensure water quality is protected while allowing excess salt to be transported out of the basin via the river itself. The assimilative capacity for a pollutant such as salinity in a water body is defined as the maximum loading of that contaminant that can be accommodated by the water body without exceeding water quality objectives or standards. These objectives are typically defined at a downstream compliance monitoring location. Technical advances in data acquisition and information dissemination technologies will be necessary for implementing a real-time salinity management program. Real-time salinity management relies on continuously recording sensors that form the backbone of a monitoring network and simulation models that forecast flow and water quality conditions in the receiving water body and the tributary watersheds that contribute flow and salt load to the river. The concept of mass balance is fundamental to all flow and water quality simulation models. Models can extrapolate the results of system monitoring since it is impossible to collect data for every drainage outlet and stream tributary in the basin. Dividing hydrologic basins into smaller drainage subbasins each with a monitoring station at their outlet can provide an efficient means of characterizing salt export loading from the watershed to surface water bodies such as rivers. This is the basis for the sort of control necessary to meet salt loading objectives at the basin-scale. Implementing the principles of real-time salinity management is underway in a USBR-funded study in the Grasslands Ecological Area. This is a 140,000+ acre tract of seasonally managed wetlands containing state and federal waterfowl refuges and privately owned duck clubs. The real-time monitoring, data sharing, and modeling needed at the basin-scale are being developed at the subbasin scale as proof-of-concept (Quinn 2009; Quinn et al. 2010).

Salt Recycling

Agricultural subsurface drainage water and concentrate from desalination facilities contains a mixture of salts as well as other dissolved minerals that have leached from the soil. In much of the San Joaquin Valley, sodium sulfate and sodium chloride are the dominant salt compositions. Salts such as calcium carbonate, calcium chloride, calcium sulfate (gypsum), and magnesium chloride are also present, but to a lesser extent. Because of the number and types of constituents in drainage water, treatment of drainage water to produce fresh water is complex and requires a high energy demand. Disposal of the salts and brines from the treatment processes also is costly. However, today's treatment technologies are being developed that use less energy, and methods are being explored to recycle economically the salts removed from the concentrated drainage.

There are available processes that separate purified salt products (e.g., sodium sulfate, gypsum, or sodium chloride) for commercial markets and the sale of product-generated revenues can potentially offset the cost to treat the drainage water. The U.S. Geological Survey (USGS) Mineral Commodity Summary prices for 2010 of some of these salts are shown in Table 19-2. The prices are in dollars per short ton (2,000 pounds).

PLACEHOLDER Table 19-2 Value of Reclaimed Water and Recyclable Salts Present in a Typical Agricultural Drainage Water Sump in the San Joaquin Valley

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

Sodium sulfate has solubility characteristics that offer the potential to recover purified sodium sulfate for commercial markets. The USGS estimates of U.S. sodium sulfate uses in 2010 were soaps and detergents (35 percent), glass (18 percent), pulp and paper (15 percent), textiles (4 percent) carpet fresheners (4 percent), and miscellaneous (24 percent). Gypsum or calcium sulfate is another mineral that can be recycled. It is commonly used in agriculture. For example, San Joaquin Valley farmland uses an average of 850,000 tons of gypsum per year (California Department of Food and Agriculture 2009).

Once purified, salts from the drainage water could also be further processed to make other useful products. For example, sodium sulfate can be converted to sodium hydroxide (caustic soda) and sulfuric acid using electrochemical technologies, both of which can be sold. The sodium hydroxide can also be used to capture and convert carbon dioxide, a GHG, into carbonates such as soda ash and other high-value chemicals.

In 2010, the chemical industry consumed about 40 percent of total sodium chloride (salt) sales and salt for highway de-icing accounted for 38 percent of U.S. demand (U.S. Geological Survey 2012). However, the most economical use of sodium chloride removed from agricultural drainage brine is likely reuse in the drainage water treatment process, e.g., softening water using ion exchange treatment. Any surplus could be sold.

After the drainage water is treated and salts and other constituents are recycled or disposed, the cleaned water can be used for irrigation or other beneficial uses. As noted in the “Collection and Storage” section above, treatment costs including removal and disposal of unwanted chemicals must be balanced with potential income to determine feasibility.

Adaptation

A very commonly employed but ultimately unsustainable management strategy is adaptation to increasingly saline conditions. This situation exists in the Tulare Lake basin that does not have a reliable natural outlet. In the absence of some mechanism to remove and dispose salts, salt imported into the basin in irrigation water, in soil amendments, for water softening, and for other purposes remains in the basin. The Water Quality Control Plan for the Tulare Lake basin recommends constructing a drain to remove the excess salts from the basin to begin correcting the problem. This option is not being pursued at this time because of cost and political considerations. Therefore, the plan also includes a strategy of controlled degradation to extend the beneficial uses of the water in this basin and the environmental, economic, and social infrastructure those uses support for as long as possible. Some land in this basin has already been abandoned due to salinization. There is additional discussion of land retirement in Chapter 32, “Other Strategies,” in this volume.

All potential alternatives must be weighed against one another as well as other resource and environmental needs to develop the best strategy for California’s different regions. For example, an evaluation of the impacts of evaporation basins should be weighed against possible alternatives such as constructing a brine line. Water conservation efforts in the Salton Sea watershed must be balanced with overall salt management for surrounding lands and potential impacts to the sea. Salt storage, while expensive and often environmentally problematic, should be researched further and new strategies for interim and long-term salt storage and salt disposal should be developed.

These debates are beginning now, partially because of the 2009 Recycled Water Policy adopted by the State Water Resources Control Board. This policy includes a requirement that local water and wastewater entities, together with local salt/nutrient contributing stakeholders, prepare salt and nutrient management plans, complete those plans, and propose them for adoption by the Regional Water Quality Control Boards within five years. The State Water Resources Control Board also committed to seek state and federal funds to cost share in the preparation of these plans (see also Chapter 12, “Municipal Recycled Water”). The resulting plans will be able to build on the case studies in this chapter, which illustrate current approaches to address problem salinity in various parts of the state. The local studies range from urban to agricultural and include collaborative efforts between regulators and stakeholders to develop and implement regional plans that encompass multiple salinity sources and an array of management options. A larger regional collaborative effort known as CV-SALTS is described in Box 19-5, containing Case Study 5, and will have spillover benefits for areas beyond the region.

PLACEHOLDER Box 19-5 Case Study 5: Central Valley Salinity Alternatives for Long-term Sustainability (CV-SALTS)

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

Potential Benefits

A number of benefits that salt management will provide can be grouped under beneficial use protection, increased useable water supplies, and economic stability.

- **Beneficial Use Protection.** As discussed earlier, the beneficial uses most sensitive to excess salt include agricultural irrigation/stock watering, municipal and domestic supply, and processing. However, other uses may be impacted as well. A few common ongoing and emerging threats which would be minimized from salt management are listed below.
  - *Salt loads containing nitrates***.** Dairy waste management, septic systems, and fertilizer use can all contribute to groundwater degradation by nitrate. Excessive nitrate salts in ground-water is a human health issue. Chapter 16, “Groundwater/Aquifer Remediation,” in this volume has additional information on nitrate contamination. Excessive nutrient salts in sur-face water can spur explosive, unwanted algal growth that not only impacts aquatic life but also interferes with recreational and commercial use of water bodies.
  - *Seawater intrusion*. Seawater intrusion into the Delta has a significant impact on the quality of water exported from the Delta. Coastal aquifers are at risk of seawater intrusion when there is more fresh water withdrawn than is recharged into the aquifer. Aquifers and surface

water are vulnerable to sea level rise and seawater brought in by storm surges that may increase in intensity or frequency because of climate change. Seawater intrusion threatens drinking water and water used for irrigation.

- *Soil and groundwater salinization*. Salinization occurs when salts are allowed to accumulate over time in soil or groundwater. Soil salinization results in a loss of soil productivity due to a chronically unfavorable balance of salt and water in the soil profile (see Figure 19-4 for the statewide current status). Groundwater salinization results in the loss of utility of an aquifer, meaning that the water no longer supports municipal or agricultural uses. Both processes are virtually irreversible.
- *Salinization of water bodies*. Water bodies with no natural outlet are primarily sustained by inflowing water and evaporation. As water evaporates, dissolved salts are left behind and begin to concentrate. These water bodies may see further increases in salinity if inflows are reduced and/or if the inflows have a high TDS concentration. Both factors are contributing to the salinity problem in the Salton Sea. The Salton Sea Species Conservation Habitat Project draft environmental impact statement/environmental impact report (EIS/EIR) reports that an environmental impact of increased salinity is an adverse effect on fish that, in turn, affects the birds that feed on them.

- **Increased Useable Water Supplies.** Salt management does not simply reduce the salt loads impacting a region; it can also improve water supplies. In some regions, dilution with low salinity water is the primary means used to manage salinity. Dilution in the right place may provide some side benefits due to increased flow (e.g., supporting aquatic life), but more often water used for dilution is water that is unavailable for other purposes at other times. Climate change will undoubtedly alter the way California manages water and altered weather patterns will likely impact the volume, location, and timing of available low salinity flows in many, if not all, parts of the state. Therefore, sustainable salt management is a key component of securing, maintaining, expanding, and recovering usable water supplies. Recovered water supplies would include recycled wastewater and brackish water desalination projects. Some water authorities in Southern California use both strategies. The issues related to recovering usable water supplies are further discussed in Chapter 12, “Municipal Recycled Water,” in this volume.
- **Economic Stability**. As a somewhat silent and long-term threat, salinity is seldom considered a key component to California’s economic stability. However, the population requires reliable drinking water sources and industries, particularly agriculture, suffer as salinity levels increase. The reality is although some communities reclaim brackish water at great expense, most California water users cannot afford to do this. Despite contributing $31.4 billion to California’s economy in 2006, several of the most productive farming regions of the state (including the Imperial, Salinas and San Joaquin Valleys) are vulnerable to soil and/or groundwater salinization. Statewide economic benefits from providing a sustainable salt and nutrient management plan for the Central Valley alone have been estimated at $10 billion by 2030 (Howitt et al. 2009).

The local benefits of sustainable salinity management mirror the statewide benefits: 1) restoring and maintaining beneficial uses of water within the basin, 2) securing and, in some cases, improving the reliability of the water supply, and 3) providing local economic stability by providing reliable drinking water sources and water quality that supports local industries. Out-of-basin benefits can also be substantial. Due to the complex water transport infrastructure in California, sustainable salt management in any hydrologic region of the state protects water resources that may be serving multiple purposes in multiple regions. For example, salinity control in the Sacramento River basin may have a relatively small direct benefit in this watershed, which normally receives high rainfall and therefore usually has adequate dilution flows to maintain salinity at acceptable levels. However, Sacramento River water flows into the Delta and reducing salt loads in tributary rivers to the Delta could provide significant benefits to those receiving water through the California Aqueduct (much of Southern California) and the Delta-Mendota Canal (approximately 1.6 million acres in the San Joaquin Valley). These benefits are higher quality drinking water, avoided costs, continued ability to produce food and fiber, habitat maintenance, and reduced pre-treatment costs for industries requiring low salinity water supplies.

Another example of an out of basin benefit is the Colorado River. Water from the Colorado River serves several states, including California, and the river carries a significant salt load. Programs currently in place to reduce salt inputs in the upper watershed benefit all downstream water users. Continued upstream salt load reductions provide continued reduction of salt imported into parts of the California where opportunities for export, treatment, or storage are limited. Any time salinity treatment can be avoided there will be significant energy savings benefits as well.

Potential Costs

Several studies have confirmed that the cost for treating the resulting problem is greater than up-front planning to avoid the issue. The stakeholder-led Central Valley Salinity Alternatives for Long-Term Sustainability (CV-SALTS) developed a five-year work plan in 2009 that identified costs as high as $50 million to characterize and develop a sustainable salt and nutrient management plan for 40 percent of California's surface area and 70 percent of its managed water supply (Central Valley Salinity Coalition and CV-SALTS 2009). The primary costs are:

- Characterizing source and fate of salinity.
- Ensuring appropriate beneficial use designation and associated water quality objectives.
- Validating industry management practices.
- Determining implementation alternatives and priorities.
- Developing a long-term monitoring network for adaptive management.

Even though the cost for the overall plan does not include implementing the projects needed to manage salts, benefits from salinity management in the Central Valley would extend to the rest of the state through improved water exports from the Delta to Southern California and the Central Coast. Due to the complexity of salt management and limited funding, the stakeholders are currently revising the priority activities for the first phase (through approximately 2014) and future efforts. Stakeholders are also coordinating with the integrated regional water management plan (IRWMP) planning and other regional efforts to assist regional planning and implementing salt management projects.

Some examples of the costs for industries and regions currently addressing salt control and/or management are highlighted below.

- Rubin, Sundig, and Berkman (2007) investigated the cost of managing TDS in the Central Valley. At food processing plants, costs for removing dissolved solids (TDS) by various means ranged from $258 to more than $8,000 per ton. For the wine industry, costs ranged from $269 to $2,300 per ton. For the dairy industry, costs ranged from $193 to $3,200 per ton. The report also estimated that the dairy and wine industries would spend up to $2,500 per ton of salt removal to use a brine line to the ocean.

- Tulare Lake Drainage District (TLDD) has investigated numerous desalination technologies for drainage water including reverse osmosis, polymer pretreatment, and distillation to develop a new source of water supply from subsurface agricultural drainage water. Numerous selenium removal technologies have also been evaluated. TLDD recently completed an enhanced evaporation spray field trial using high pressure spray nozzles to increase natural solar evaporation. The total cost expended exceeded several million dollars.
- The Santa Ana Watershed Project Authority (SAWPA) with the help of state low interest loans and grants committed well over $100 million to construct a regional brine line serving all areas of the Santa Ana River watershed (see Box 19-4). Additionally, stakeholders in the watershed spent several million dollars and more than 10 years developing a basin-wide salt and nutrient management plan to provide for sustainable management. The plan uses the brine line and continued building of more than 10 ground water desalters to remove salts and nitrates from the groundwater. Most desalters have an initial capital cost of $20-40 million.
- The City of Dixon (population 18,000) located on the west side of the Central Valley recently completed a study to reduce the city's wastewater chloride load to the groundwater by 30 percent (City of Dixon 2011). Key findings include:
  - All else being equal, 20 percent conservation can result in 25 percent concentration. Average household costs to mitigate this amount appear to range from approximately $3 to $60 per month.
  - Impacts of residential communities and agriculture are roughly equivalent acre for acre with the same water source.
  - Source control and land fallowing are roughly equivalent on a cost basis and both are an order of magnitude (10 times) less expensive than salt removal treatment.

Table 19-3 lists the estimated cost to Dixon by project.

PLACEHOLDER Table 19-3 Incremental Costs to Remove or Mitigate Approximately 30% of the City of Dixon's Municipal Wastewater Chloride Load to Local Groundwater

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

It is extremely difficult to estimate the cost of a statewide strategy for sustainable salt management apart from water management itself. Ideally, salinity control should be, and most often is, incorporated into broader efforts to protect or expand water supplies, optimize water use, offset land subsidence, protect fisheries, or store water for future use. Salt management methods vary in effectiveness and cost depending on a variety of factors including:

- Volume and concentration of salts.
- Type of salts and stability of salt stream.
- Other materials or contaminants present.
- Desired salt concentration after management.
- Use of the water after treatment.
- Disposal of salt removed as part of a treatment process.
- Type of salt management strategies used:
  - Prevention.

- Salt minimization.
- Salt removal from process.
- Salt removal from groundwater or environment.

Disposal of salt is a particular concern in inland areas that use desalinated water as a part of their water supply portfolio and have no access to an ocean outfall line. Two major strategies for brine disposal for these areas include 1) deep well injection and 2) evaporation basins. Several other strategies for using waste brine have been proposed which include irrigation of salt tolerant plants and brine shrimp harvesting. Such approaches have been limited and tend not to be applicable to very large volumes of wastewater. Recovery of inorganic salts with potential commercial value has also been suggested, but has not demonstrated economic viability to date.

While cost variability is high, multiple salt management options are often necessary because the least-cost salt management options appropriate for a given area may be inconsistent with sustainability when considered in a broader context of local, regional, or statewide salt management, energy consumption, water availability, or other resource issues.

Major Implementation Issues

Major issues facing successful salt and salinity management in California include the lack of:

- A common understanding of the need.
- Regional framework to address management issues on a holistic scale.
- Consolidated/validated water flow and quality data for sound decisions.
- Feasible treatment alternatives.
- Stable funding.

In addition, climate change must be considered when addressing these major issues.

Common Understanding

Historically, salinity has not been a high profile issue to the general public although the local impacts of salinity have been severe in certain parts of California such as in the Salinas Valley, the Tulare Lake basin, the Lower San Joaquin River basin, the Colorado River basin, and the Santa Ana River watershed. Damage to the soils and groundwater from salt generally occurs over decades rather than hours, days, or months as occurs with many toxic constituents. Californians increasingly recognize that high quality water is a limited resource that once salinity concentrations become excessive the available and technically feasible recovery options are likely to be very expensive, adaptation to increasing salinity is an interim measure at best, and that water quality protection is more cost-effective and has a greater chance of success than water quality remediation. Salinity concentrations and loads can be impacted by most of the resource management strategies discussed in this chapter and must be considered as an integral component in all resource management strategies.

Understanding the need for salt management is only a first step. California has additional major challenges to implement sustainable salt management.

Regional Framework

Each hydrologic region has its own priorities and limitations on the resources available to address those priorities. Salt management has not kept up with emerging salt problems in many parts of California. As a general rule, salt management has been reactive rather than proactive in many parts of the state. Problem salinity emerges and a plan is formulated to deal with it; or problem salinity is anticipated and a plan is formulated, but the plan is not implemented completely or is not flexible enough to adjust to changing conditions like ecosystem or other water quality priorities. Sustainable salt management will require a more concerted, coordinated, and proactive planning effort than most communities or regions of the state have been able to achieve to date. This planning should be integrated with other water management alternatives and it could result in efficiencies and cost reductions for salt management. In particular, salt management strategies should be included in integrated regional water management planning efforts.

Effective salt management may also be constrained by federal, state, and local policies crafted to serve other needs. This inadvertent constraint is a similar problem to the funding issues discussed below. Very few public policies were developed with salt management in mind. As a result, water use and reuse, prioritization of resources, pollutant control, land use, and habitat management policies, to name a few, may be inconsistent with optimal salt management. Also, vis-à-vis, optimal salinity management may impact numerous other resources and management strategies. Historically, water management decisions have been driven primarily by water use efficiency policies, often with no consideration of the salinity issues. Consumptive use of water always results in the concentration of the total salt load in that water. As California uses water more efficiently, supplies will tend to become more saline unless policies and practices are intentionally implemented to maintain salinity at acceptable concentrations. Compromises between efficiency and quality will likely be needed to ensure a sustainable water supply for future generations.

Salinity problems often stem from decisions and actions taken elsewhere, but the costs to manage salt are generally borne by the receiving basin, watershed, community, or individual water user. Salt problems are rarely attributable to a single cause, but rather reflect a suite of decisions, conditions, conflicting water needs, and shifting state and local priorities. Problem salinity in California, as in other parts of the country and other parts of the world, can often be traced back to decisions that seemed like a good idea at the time but that did not take into account the long-term impacts of salinity. A significant example of this is the operation of the Central Valley Project (CVP) and the State Water Project (SWP), which move water and the associated salt loads from one basin to another around the state in order to meet water supply needs while operating to Delta water quality objectives set by the SWRCB (Figure 19-4). A few additional examples follow.

- The Hetch Hetchy and Pardee Reservoirs serve as a water supply for San Francisco and East Bay Municipal Utility District respectively, diverting high quality water supplies from their basin of origin. These flows would otherwise assist in salt management by diluting the concentrations of salts downstream in the San Joaquin River basin and Delta, though the potential trade-off may be increased salinity in Bay Area water supplies.
- Planning for drainage facilities in the San Joaquin Valley began in the mid-1950s. Drainage service was initially considered at the time the USBR first studied the feasibility of supplying water to the San Luis Unit. By 1975, an 82-mile segment of the San Luis Drain, ending at Kesterson Reservoir, had been completed and 120 miles of collector drains were constructed in a 42,000 acre area of the northeast portion of the Westlands Water District. In 1983, the

discovery of embryonic deformities of aquatic birds at Kesterson Reservoir due to high selenium in drainwater significantly changed the approach to drainage solutions in the San Joaquin Valley. Discharges to Kesterson Reservoir were halted and feeder drains leading to the San Luis Drain were plugged. Multiple lawsuits later, the San Luis Drainage Feature Reevaluation Plan Formulation Report in 2002 and draft EIS in 2005 (U.S. Bureau of Reclamation 2002, 2009) identified the In-Valley Disposal/Water Needs Land Retirement Alternative as the proposed action to provide drainage service based on cost, implementation, and other environmental information. In May 2003, the Westside Regional Drainage Plan was developed as a collaborative effort between the San Luis Unit water districts and the San Joaquin River Exchange Contractors Authority to provide drainage relief in portions of the Unit and adjacent areas (San Joaquin River Exchange Contractors Water Authority et al. 2003). The Westside Regional Drainage Plan is currently being implemented by its proponents and with the assistance of state and federal funding. However, salt loads are continuing to accumulate in the basin.

- Los Angeles basin biosolids are exported and applied to land in Kern County. In the process of providing agricultural benefits (porosity, soil tilth, etc.), this activity is also relocating salt to the Tulare Lake basin that is already under salt stress.
- In Southern California, only about half of the region's salt comes from local sources. The rest is brought in with imported water (Figure 19-5). The Colorado River Aqueduct imports the highest volume of salt to the South Coast hydrologic region with an average concentration of approximately 640 mg/L TDS, measured at Parker Dam. Water imports from the SWP and California Aqueduct have better water quality than other imports, but still have higher salt levels than many local basins. Elevated salt concentration leads to waterscaling problems for indoor plumbing appliances and equipment in homes, business, and industries which contributes to a consumer choice to install water softening equipment, exacerbating the overall problem.
- Imported water from the Colorado River in the Imperial and Coachella Valleys has a high salinity concentration averaging 745 mg/L TDS measured at Imperial Dam. This brings an estimated 3.1 million tons of salt annually to these valleys.

PLACEHOLDER Figure 19-5 Federal and State Water Projects

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

Consolidated/Validated Flow and Water Quality Data

Salinity monitoring in surface and groundwater in most regions is under-funded, insufficiently coordinated, and has inadequate coverage to properly indicate the salt situation in most regions. Coordinated monitoring is the only way to assess salt impairment, track the rate of salinity degradation or improvement, and determine the effectiveness of salt management actions. Coordinating efforts not only lowers the costs of monitoring, but can also assist to make sure that all components needed to develop realistic water and salinity budgets are properly estimated. Sometimes overlooked is the fact that a reliable water budget is necessary to develop a useful salinity budget. Measuring or estimating the hydrologic components of seepage, evapotranspiration, inflow, and outflow for a region of interest can be exceedingly difficult but is necessary since the water budget is the basis of all hydrologic simulation models used for decision-making.

Data needs for decision tools have increased as models are formulated with greater precision, demanding greater spatial and temporal resolution. Fortunately, environmental monitoring technology has become progressively less expensive during the past decade and allows discrete sampling technologies to be replaced by continuous sensors and inexpensive telemetry systems to obtain real-time access to data. While the multi-agency California Water Quality Monitoring Council, established in 2009, attempts to move toward broader coordination, limited resources have been made available for the effort.

Feasible Treatment Alternatives

Environmentally and economically feasible options for sustainable salt collection, storage, and disposal do not currently exist for many parts of the state. Supporting beneficial uses when water is becoming increasingly saline often means that salt must be harvested from the water periodically and then disposed. Treatment technologies, like reverse osmosis or distillation, generate a highly saline solid or liquid waste product. Some areas, such as the Santa Ana River watershed, have pipelines that take brine from inland areas, treat the brine, and discharge it to the ocean where it mixes with the salt already present. However, many of California's interior valleys do not have this option. A few facilities use deep-well injection to sequester saline wastewater and some areas use low-tech solutions such as evaporation basins to isolate and store collected salt. Both of these alternatives are expensive and can be used only in areas where the geology and soil structure support this type of management. In addition, evaporation basins require significant land area and may have environmental impacts requiring mitigation. Other areas are investigating strategies such as Integrated Farm Drainage Management which applies saline water progressively to more saline-tolerant crops. Case Study 2 (Box 19-2) is a farm-level example that ultimately disposes the remaining drainage in a solar evaporator, while Case Study 3 (Box 19-3) is a regional system that blends drainage with freshwater for reuse. Although these systems show promise at the regional scale, long-term salt accumulation is still a major issue for any reuse approach. Some saline discharges simply cannot be managed feasibly, sustainably, or economically with the management tools currently available.

Stable Funding

Funding to support salt management planning, project development, project operation and maintenance, and salinity monitoring has been insufficient in most parts of the state. With very few exceptions, public funding dispersed through grants or loans to agencies and organizations has excluded or severely limited funding for salinity planning efforts. Salt management on the scale needed for sustainability in California will require a lot of coordinated planning at the local and regional levels.

Grants and loans targeting project development and operation also often fail to support salt management, since the programs are usually competitive and award caps may favor multiple small projects over a smaller number of larger coordinating projects. This strategy is effective for some purposes (e.g., funding irrigation efficiency improvements on multiple farms across a large geographic area), but may be counterproductive for salt management which is often more cost-effectively achieved at a sustainable level through community-, watershed-, and regionally-scaled efforts (see Case Studies 1, 3, and 5, in Boxes 19-1, 19-3, and 19-5, for examples).

Project maintenance and closure is often overlooked in budgeting for salt management. However, like the example of the incomplete San Luis Drain (discussed above in "Regional Framework"), the unforeseen environmental consequences of incomplete or abandoned salt management projects can result in greater hazards than if the project had never been undertaken. Sustainable salt management will need sufficient funding to ensure that salt management projects are maintained and closed properly and adapt to unforeseen environmental issues that may occur. Timely and adequate investments in salt management will ensure that salt control projects do not exacerbate existing salt conditions.

These examples above illustrate California's need for long-term planning to deal with the ultimate disposal or long-term sequestration of salt and equitable distribution of salt management costs. Salt disposal and re-location are not simply local engineering problems, but may potentially pose economic, social justice, or environmental problems as well as opportunities for the state.

California's communities, watersheds, and regions can only achieve a sustainable salt balance if the salt leaving the area equals or, in the case of many areas with basins already out of balance, exceeds the amount of salt received. The state's "plumbing" — the natural and constructed conveyance systems that move water and drainage around the state — is not optimized for salt management. It may not be possible to achieve sustainable salt management solely through conveyance system changes, but there should be studies conducted to quantify the benefits of optimizing conveyance systems for the additional purpose of salt management.

Climate Change

Climate change projections indicate that the Pacific Ocean level along the California coast will rise by 14 inches on average by 2050 and as much as 55 inches by 2100 (State of California Sea-Level Rise Task Force 2010). Sea level rise and associated storm surges and tidal flows will increase seawater intrusion in coastal groundwater basins and in the Delta. Furthermore, increased temperatures will increase evapotranspiration rates, leading to changes in crop planting and salt deposition from fertilizer use.

Adaptation

The Delta and coastal groundwater basins can be protected by counterbalancing seawater intrusion with freshwater flows. For the Delta, this means allowing more freshwater to flow into the Delta from upstream. Nevertheless, using upstream freshwater flows for protecting against seawater intrusion could have legal and economic implications for downstream water rights holders. For coastal groundwater basins, it means reducing pumping, moving pumping inland, and creating intrusion barriers with low-salt recycled water similar to Orange County. Reducing application of salts in agricultural and industrial processes will also protect groundwater basins for continued use. Moreover, desalination of brackish water may help manage salt accumulation in some areas.

Mitigation

Protecting coastal groundwater basins as water supply sources can reduce the need to rely upon more energy-intensive forms of water supply, minimizing GHG emissions. Creating seawater intrusion barriers and brackish desalination can be high-energy processes that negatively impact climate change mitigation efforts. In inland areas, salinity management could involve more high-energy treatment techniques. Alternately, reduced application of fertilizer could lower GHG emissions from fertilizer production.

Recommendations

Salt and salinity management is a long-term commitment for California. Recommendations have been broken into two parts: short-term (5-10 years) to provide a solid framework on which to build and long-term/on-going to support regional/statewide management and implementation alternatives. Since the success will depend on a stable funding base, a separate recommendation for potential funding alternatives is included in Chapter 7, "Finance Planning Framework," in Volume 1. The following recommendations are complementary to other water quality resource management strategy recommendations because salt and salinity management is strongly tied to all elements.

Short-Term (5-10 Years)

1. **Address Priority Concerns.** Legislature should identify and prioritize planning and implementation funding to areas where salt and nitrate management have immediate and/or widespread benefits including:
   A. Areas with impacts to drinking water as identified in State Water Resources Control Board's Report to the Legislature on Communities that Rely on Contaminated Groundwater (Assembly Bill 2222, Statutes of 2008) and State Water Resources Control Board's Report to the Legislature on Addressing Nitrate in California's Drinking Water with a Focus on Tulare Lake basin and Salinas Valley Groundwater (Senate Bill X2 1).
   B. The Central Valley where improvements would benefit not just the valley, but also significant portions of California receiving water exported from the Delta.
2. **Support Regional Management.** Existing programs, such as the IRWM Grant Program and others, should prioritize funding to groups updating regional plans that include salt and nutrient management components or implementation projects, giving higher funding preference to areas with disadvantaged community participation, areas identified in Recommendation No. 1 above, and small water systems and individual wells with documented contamination.
3. **Centralize Validated Water Quality and Flow Data.**
   A. State agencies should provide support and funding for the California Water Quality Monitoring Council as it continues to evaluate and promote coordinated monitoring and data management throughout the state.
   B. As financially feasible, projects receiving state money for salt management should be required to follow appropriate quality assurance protocols and submit salt data to a publicly accessible database.

   Improved hydrological and water quality database management tools are critical to facilitate easier access and data sharing necessary for the success of basin-wide salinity management. Decision support requires timely and accurate data that will require a greater degree of collaborative sharing than exists at present. Discrete flow and water quality data is no longer sufficient for decision-making. Maintaining high quality continuous sensor data will require a significant investment in state-of-the-art information technologies such as screening and data quality control software that runs on web-based data servers. Adopting common data platforms, or at the very least, agreeing on hydrologic data management conceptual protocols such as ArcHydro and ArcHydro Groundwater, would go a long way to encourage data sharing and improve data access.
4. **The State should review its funding guidance and policies for consistency with sustainable salt management and make revisions where necessary.** Specifically:

A. Legislated grant and loan programs (including Proposition 84) should address salt management differently than other constituents and favor projects that coordinate with a regional salt management plan and are supported by the entities maintaining the regional salt plan.
B. When not explicitly prohibited by statute, public funding proposal solicitations should welcome projects with community-, watershed-, and regional-scale planning (specifically salt management planning) and water quality monitoring components.
C. Award caps should be consistent with implementation of community-, watershed- , and regional-scale salt management projects.
D. All salt management projects receiving public funding should be required to provide the awarding agency with an assurance that sufficient funding will be available to maintain the project during its life. These salt management projects should close in an environmentally acceptable manner based upon what can be foreseen at the time of project proposal.

Long-Term and Ongoing Needs

5. **Salt Storage and Other Research and Implementation.** Additional options for salt collection, salt treatment, salt disposal, and long-term storage of salt should be developed. University researchers should work with regulatory agencies and stakeholders to identify environmentally acceptable and economically feasible methods of closing the loop on salt for areas that do not currently have sustainable salt management options. Funding for this sort of research should be prioritized to ensure that areas with the greatest needs (i.e., high salt and few or no feasible management options) are targeted first (see recommendation No. 1). Specifically:
   A. Invest in research and development of environmentally acceptable means of storing salts for extended periods (decades) and sequestering salts (100+ years). Research should include identifying areas where such facilities can be sited with the least environmental impacts.
   B. Encourage additional research into more feasible means of using collected salt.
   C. Continue to evaluate an out-of-valley conveyance for the Central Valley such as a regulated brine line similar to the Santa Ana River Interceptor (SARI) system.
6. **Policies.** Entities with water policy-making authority should review existing policies, including those related to water use efficiency and funding of water projects, for consistency with sustainable salt management. Revisions should be made where necessary to ensure consistency with long-term sustainability objectives for multiple resources (e.g., water and energy). Effective salt management is not a stand-alone strategy and it should be integrated with other strategies. Every water use, water reuse, and waste disposal decision should include consideration of how the decision may affect the local and regional salt balance. Projects that propose to introduce saline water that may eventually mix with groundwater should be evaluated in the context of the basin's assimilative properties, California's Antidegradation Policy, and potential impacts on a broader holistic scale to allow for a systems management approach.
   When developing new policies and long-term strategies consideration must be given to policies adopted as the basis for ongoing activities. A good example is the policy to develop a Central Valley Drain to mitigate salt import and drainage impacts when extensive water supplies were provided through the Central Valley Project (CVP).
7. **Planning.** DWR and the USBR should actively participate in the Central Valley Salinity Alternatives for Long Term Sustainability (CV-SALTS) and other regional planning groups to de-

velop regional salinity management plans that would include their respective water projects. These regional plans should include:

A. An assessment of salt sources, loads, and timing.
B. Current and projected regional water use with a description of projects.
C. An assessment of conveyance flexibility to minimize/maximize exportation of salts.
D. Land use planning based on regional/state projections.
E. A regional implementation strategy, which could include offsetting/reducing salt loads relocated to salt-stressed interior basins as a result of water project operations. For example, USBR and the Central Valley Regional Water Quality Control Board entered into a Management Agency Agreement in December 2008 to address salinity brought into the San Joaquin basin via the Delta Mendota Canal. After 2008, USBR will implement its Action Plan to quantify offsets from current mitigation projects and continue to implement existing projects.
F. A funding strategy that supports the implementation strategy, including providing funding and staff to participate in and support the CV-SALTS initiative and other regional planning groups.
G. A stakeholder participation process to increase the likelihood of achieving plan goals and to ensure transparency in project planning and implementation.
H. A monitoring program to track the success of the implementation strategy.
I. An adaptive management strategy that ensures the plan can be modified to respond to drought, emergencies, climate change, and other changes and needs appropriately.

Also, federal, state, and local entities with planning authority should review their planning documents (i.e., integrated regional water plans, basin plans, general plans) for consistency with sustainable salt management balanced with other resource management decisions and make revisions where necessary. Plans serving areas where salt accumulation in groundwater is currently unavoidable should address options for extending the life of the aquifer including, but not limited to, source control strategies and construction of salt disposal or long-term storage facilities. These plans are living documents. Therefore, salt management sections should be updated in accordance with salt management actions that have been taken (or in response to expanded salinity problems due to actions not taken) as well as other resource management activities since the previous review.

8. **Federal Coordination.** The federal government should ensure that all federal facilities are contributing their fair share to mitigate any federal facility's impact to salt imbalances in California's communities, watersheds, and regions and participate in regional salt management efforts where appropriate.
9. **Expanding Coordinated Monitoring and Standardization.** Federal, state, tribal, local, nongovernment, and private stakeholders should work collaboratively to fund, develop, and operate a monitoring network or an array of compatible networks capable of identifying emerging salinity problems and tracking the success of ongoing salinity management efforts where such networks do not already exist. New or expanded networks should build upon and remain compatible with existing statewide monitoring programs such as the Surface Water Ambient Monitoring Program (SWAMP) and Groundwater Ambient Monitoring and Assessment (GAMA) program. Data should be made available to the public through a web-based user interface such as the Integrated Water Resources Information System (IWRIS). Many water districts and agencies, such as the U.S. Fish and Wildlife Service, have chosen commercial data platforms such as WISKI (developed by Kisters North America) to collect, maintain, and share data. This

software provides a high level of security allowing these water districts and agencies to share data on their own web servers. This data may be valuable to other water districts and outside agencies and this software prevents universal access to more sensitive data. If widely adopted, this technology may have an important role in eliminating some of the current monitoring redundancy and optimizing use of scarce monitoring program funds.

The tools and data resources currently available to assess salt balance are inadequate as previously discussed. Salt balance analyses should be based on calibrated regional surface and groundwater hydrology models where possible, since these models supply a standardized conceptual schema for defining basin, hydrologic, and institutional boundaries and provide a widely accepted protocol for defining layer boundaries with aquifer depth. Having this degree of standardization will allow valid comparisons to be made between salt balance, between regions, and will support more creative approaches using visualization techniques to convey the concepts of salt balance, rates of change, and long-term sustainability to stakeholders and the public.

Conclusion

Salt moves with water statewide. Therefore, effective salinity management should address the routes water takes within and between basins. All entities that make decisions with a bearing on water management should participate in regional salt management planning, monitoring, and implementation projects. In specific arid areas of the state, salt may also be displaced by air (e.g., Owens Valley) and such potential displacement must also be considered during planning efforts. Salinity stakeholder groups should conduct outreach aimed at educating specific target audiences with the ability to influence salinity decisions (Legislature, state and local agencies, interest groups, general public) about the need for sustainable salinity management.

Effective and sustainable salt management decisions rest in the hands of a wide range of water managers, regulators, facility operators, policy makers, landowners, and other stakeholders in any given watershed. These entities should strive to coordinate their efforts where possible in order to use resources efficiently, develop regional solutions to regional problems, optimize funding opportunities, and achieve a salt balance in the basin as quickly as possible.

Californians can continue paying for salt management reactively as rates increase, equipment wears out prematurely, food costs soar (loss of farmland means higher transportation costs for imported food), fish and wildlife habitat is lost, and business and development opportunities disappear as operations leave the area for states with more favorable water conditions. Alternatively, Californians can pay proactively through adequate continuous funding of sustainable salt management. With so much at stake on statewide, community, and personal levels, funding for salt management cannot be solely a state or federal responsibility.

Salt and salinity management is intertwined with almost all other resource management strategies. California cannot afford to wait to address this overarching issue.

Salt and Salinity Management in the Water Plan

[This is a new heading for Update 2013. If necessary, this section will discuss the ways the resource management strategy is treated in this chapter, in the regional reports and in the sustainability indicators.

If the three mentions aren't consistent, the reason for the conflict will be discussed (i.e., the regional reports are emphasizing a different aspect of the strategy). If the three mentions are consistent with each other (or if the strategy isn't discussed in the rest of Update 2013), there is no need for this section to appear.]

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Table 19-1 Example of Impacts of Salinity on Three Beneficial Uses

Beneficial Use	Salinity Threshold (µS/cm) [a]	What Does the Target Protect?
AGR	Variable	The Food and Agriculture Organization of the United Nations (FAO) notes that an EC of 700 µS/cm protects the most salt-sensitive crops under normal irrigation operations. Ayers and Westcot describe how the target can be shifted somewhat by adjusting irrigation practices.
MUN	900 (long-term) 2200 (short- term)	This range of numbers, used by the Department of Public Health, is based on taste thresholds. Health-based standards exist for concentrations of specific ions such as nitrate and chloride.
PRO	Variable	The basin plans do not cite a threshold value to protect industrial process use, but it is known that some industrial processes require low salinity water.

a Electrical conductivity reported in microsiemens per centimeter (µS/cm).

Table 19-2 Value of Reclaimed Water and Recyclable Salts Present in a Typical Agricultural Drainage Water Sump in the San Joaquin Valley [a]

Water Composition					
	% Weight	Weight (ton)	Value ($/ton)	Unit Value ($)	% Value
Water [H_2O]	98.77%	1,359	0.25	340	13.83%
Calcium Bicarbonate [$Ca(HCO_3)_2$]	0.03%	0.34	50	17	0.12%
Calcium Sulfate [$CaSO_4$]	0.18%	2.41	33	79	3.57%
Boron as boric acid [$B(OH)_3$]	0.01%	0.18	360	64	3.75%
Sodium Chloride [NaCl]	0.42%	5.73	35	201	7.08%
Magnesium Chloride [$MgCl_2$]	0.08%	1.14	300	342	14.38%
Sodium Nitrate [$NaNO_3$]	0.05%	0.70	390	274	10.40%
Potassium Chloride [KCl]	0.00%	0.01	600	8	0.09%
Selenium [Se]	0.00%	0.001	70,000	96	4.35%
Sodium Sulfate [Na_2SO_4]	0.47%	6.41	140	897	42.43%
TOTAL	100.00%			$2,319	100.00%

Source: U.S. Geological Survey, Mineral Commodity Summaries (2009) and ICIS Chemical Business (2009).

[a] Drainage Water Volume, af: 1

Drainage Water Weight, tons: 1,359

Conductivity, dS/cm: 15,735

Total Dissolved Salts, mg/l: 11,733

Salt Volume, tons: 16

Table 19-3 Incremental Costs to Remove or Mitigate Approximately 30% of the City of Dixon's Municipal Wastewater Chloride Load to Local Groundwater

Project description	Capital cost (in million $)	Annual O&M cost (in million $)	Total Cost [a] (in million $)
Public education, source characterization studies, residential water softener ban / incentive program	$0.42	$0.16	$2.8
Fallowing of farmland that relies on low quality tailwater and/or groundwater for irrigation	$1.5	$0.10	$3.0
Injecting high quality surface water into groundwater	$3.6	$0.20	$6.6
Blending high quality surface water with wastewater treatment plant effluent	$6.3	$0.18	$9.0
Change wastewater treatment process to activated sludge (high rate/bubble aerated) treatment	$9.5	$0.14	$12
Chloride removal from groundwater by reverse osmosis	$9.0	$0.35	$14
Chloride removal from the wastewater treatment plant effluent by electrodialysis reversal	$20	$0.49	$27
Change drinking water source of supply from groundwater to surface water	$45	$0.70	$55
Install water softeners at drinking water well sites	$32	$2.0	$62

Sources: City of Dixon DRAFT Wastewater Facilities Plan, August 2011, Stantec (conceptual peer review by Brown and Caldwell). Website: http://www.ci.dixon.ca.us/index.aspx?nid=190. Technical Memorandums for City of Dixon, ECO:LOGIC, and Stantec. Personal communications with city staff and commercial dischargers.

[a] Total costs presented as 20 year Present Worth, assuming 3% net interest rate.

Figure 19-1 Relationship between Salt and Salinity Management and Other Resource Management Strategies

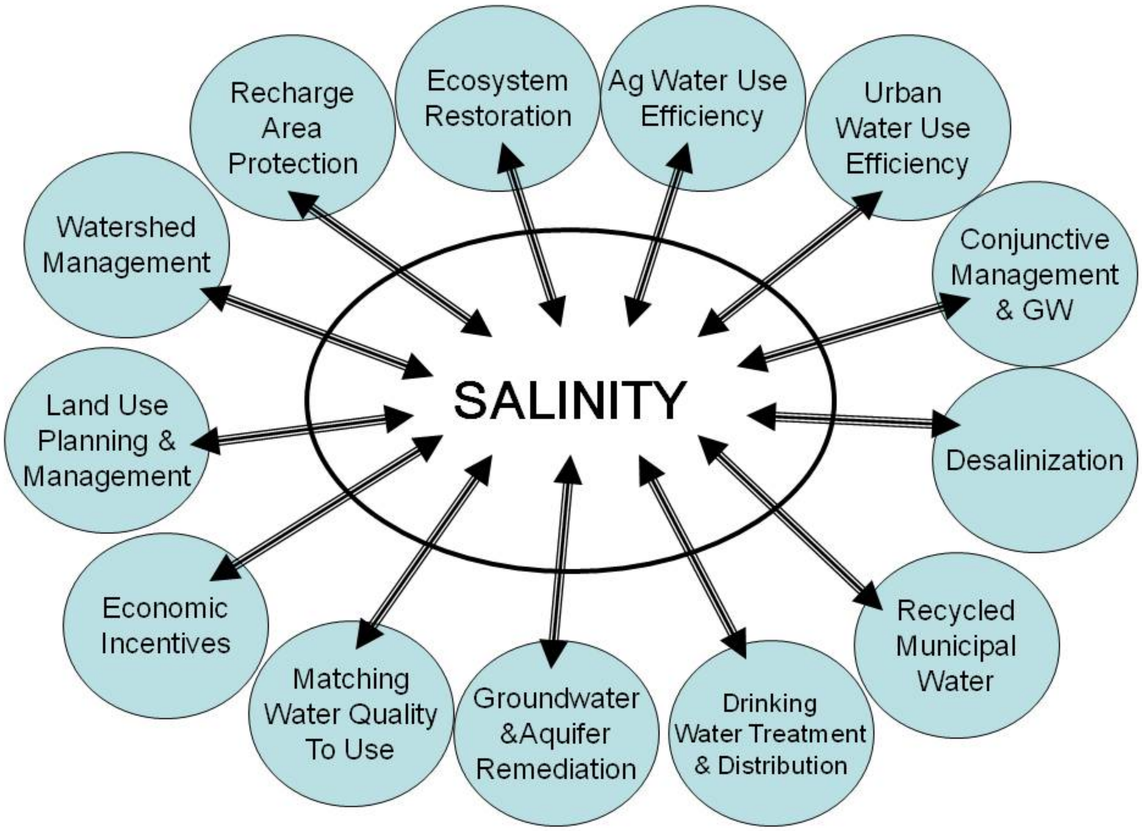
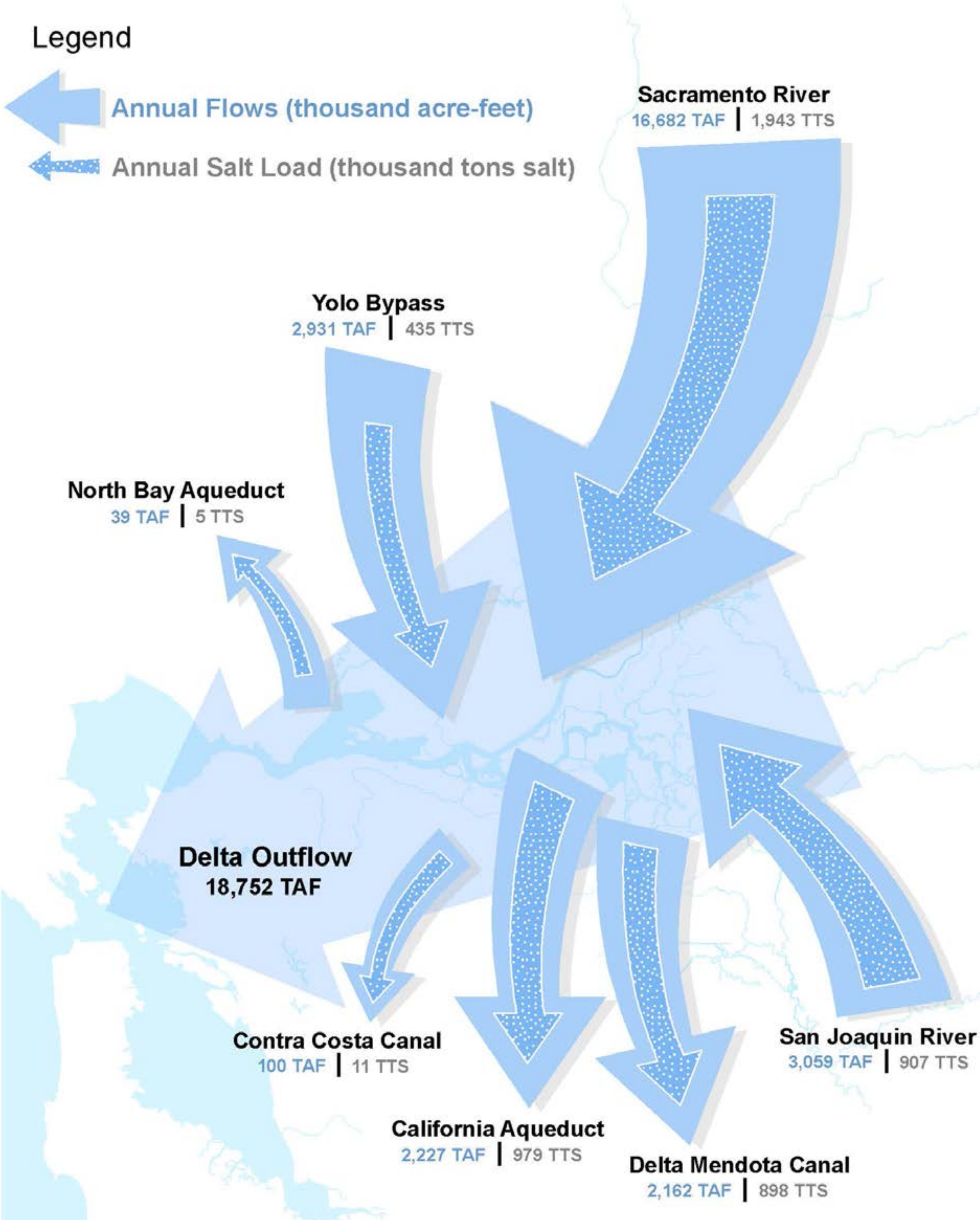


Figure 19-2 Salt Load (Mean of Annual Averages from 1959 to 2012)



Source: Department of Water Resources and the U.S. Bureau of Reclamation

Figure 19-3 Salt Loads Comparison: Existing South Delta State and Federal Pumping Plants Intakes vs. Proposed Delta Conveyance Tunnels

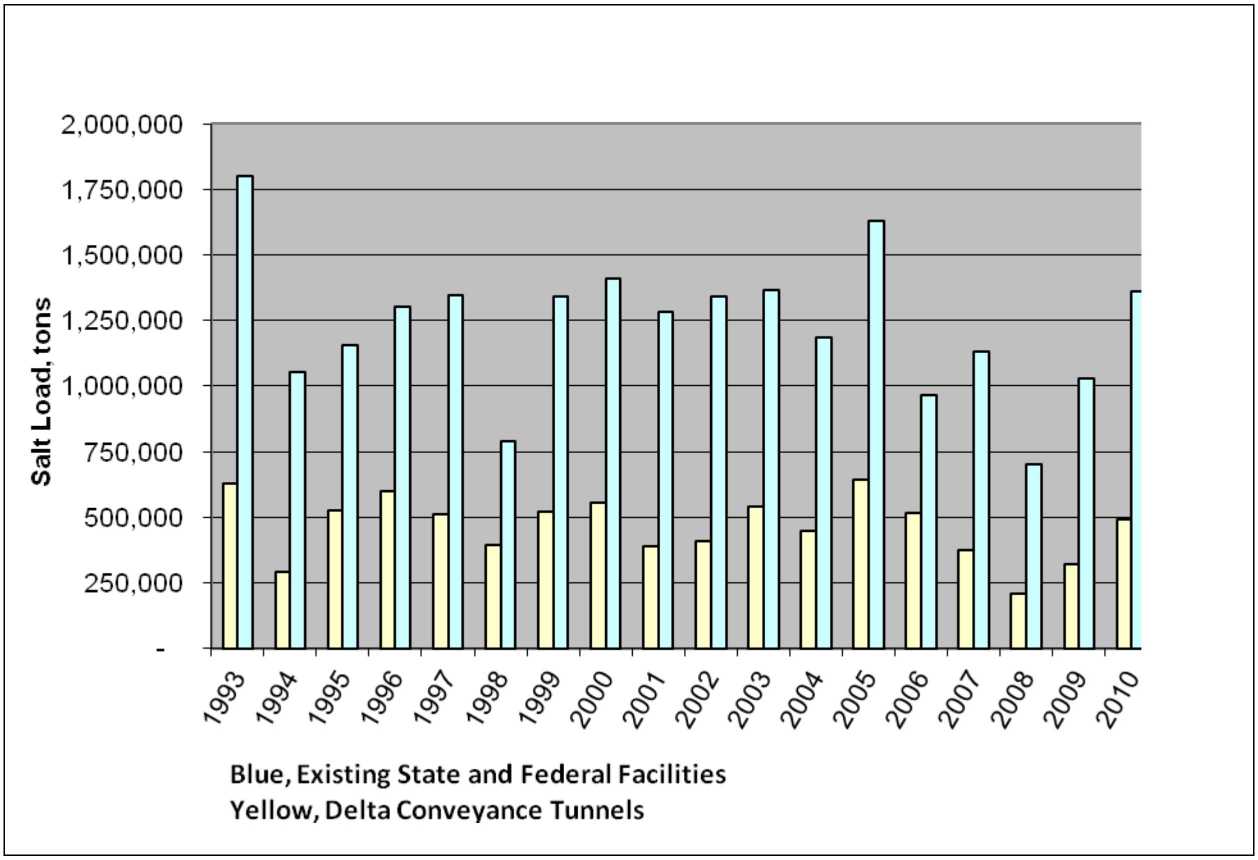
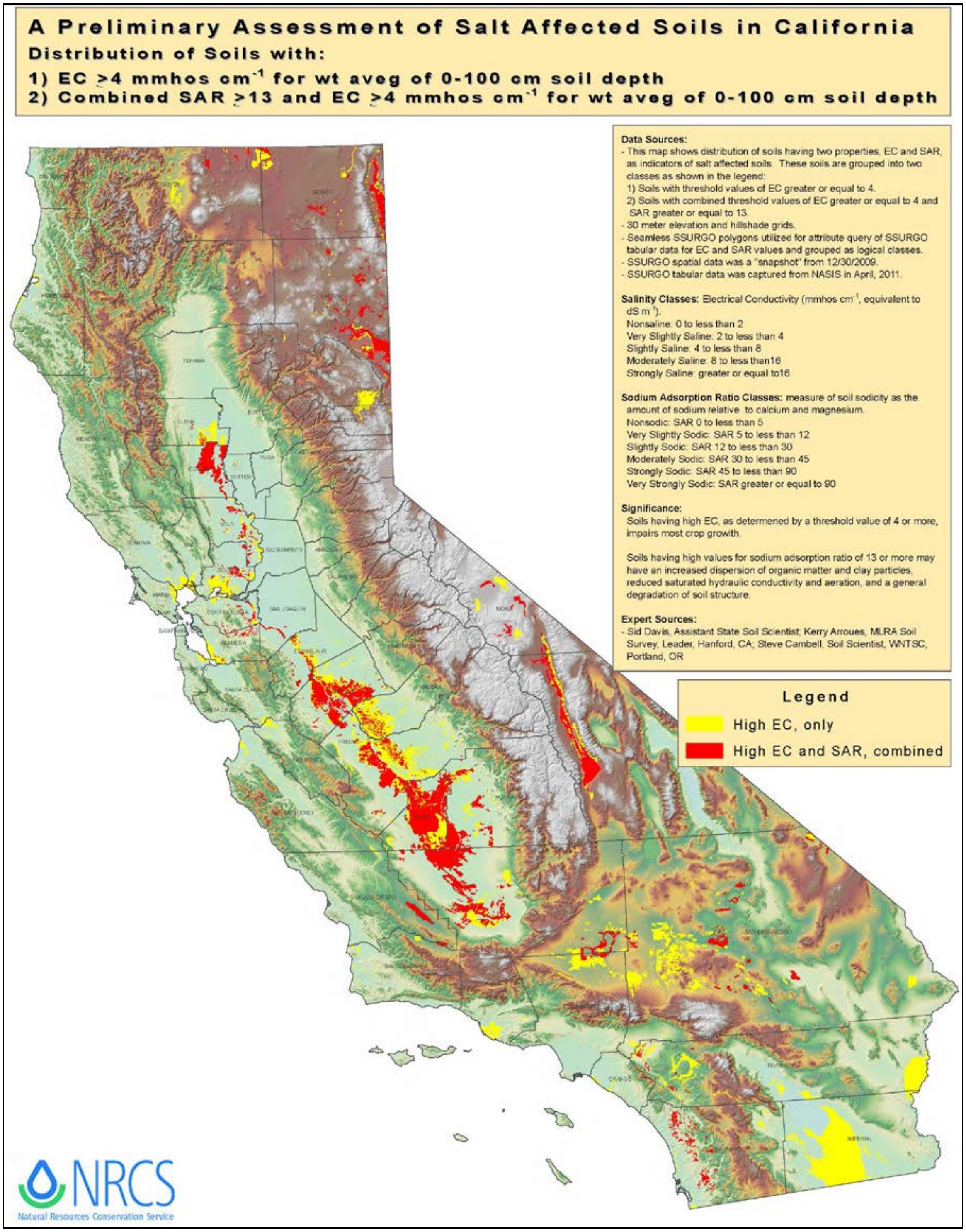


Figure 19-4 Areas of California Soils with High Salinity and/or Sodicity (USDA)



Source: USDA Natural Resource Conservation Service

Figure 19-5 Federal and State Water Projects

Source: Department of Water Resources and U.S. Bureau of Reclamation

Box 19-1 Case Study 1: Santa Clarita Valley Automatic Water Softener Project

In 2002, the Los Angeles Regional Water Quality Control Board adopted a chloride Total Maximum Daily Load (TMDL) for the Upper Santa Clara River that became effective in 2005. Implementation of the TMDL included special studies to identify sources of chloride in the region and to look at appropriate chloride thresholds for the protection of salt sensitive agriculture, endangered species, and groundwater. Significant sources of chloride in the region included the potable water supply, which included chloride from imported State Water Project water and from industrial, commercial, and residential users of the sewer system. (The State Water Project diverts water from the Sacramento-San Joaquin Delta and delivers it to Southern California. In drier years, greater proportions of saltier seawater and San Joaquin River water are exported by the State Water Project and chloride concentrations therefore increase.) The largest controllable source of chloride, contributing approximately one-third of the chloride in the wastewater, was from residential self-regenerating water softeners (also known as automatic water softeners) discharging to the sewer system.

Source control through removal of the automatic water softeners (AWS) was considered the most cost-effective way of removing chloride from the wastewater treatment plant discharges to the Santa Clara River, compared to more costly and energy intensive alternatives such as treatment through reverse osmosis. In 2003, a prospective ban on AWS installations was enacted and a voluntary buy-back program was initiated for existing AWS. In 2006, new legislation was enacted which granted the Santa Clarita Valley Sanitation District the authority to require the removal of all existing residential AWS if approved by a vote of the District's ratepayers. In 2008, the Santa Clarita Valley Sanitation District's voters passed Measure S, which required removal of all existing residential AWS. To date, the Santa Clarita Valley community has removed more than 7,900 AWS, which has significantly reduced chloride levels in the treated wastewater discharged to the river. Although further chloride reductions are required to comply with the TMDL, the unprecedented removal of AWS made major strides in lowering chloride levels in the treatement plant discharges and will significantly reduce the cost of compliance to the community.

PLACEHOLDER Figure A Santa Clara River Watershed

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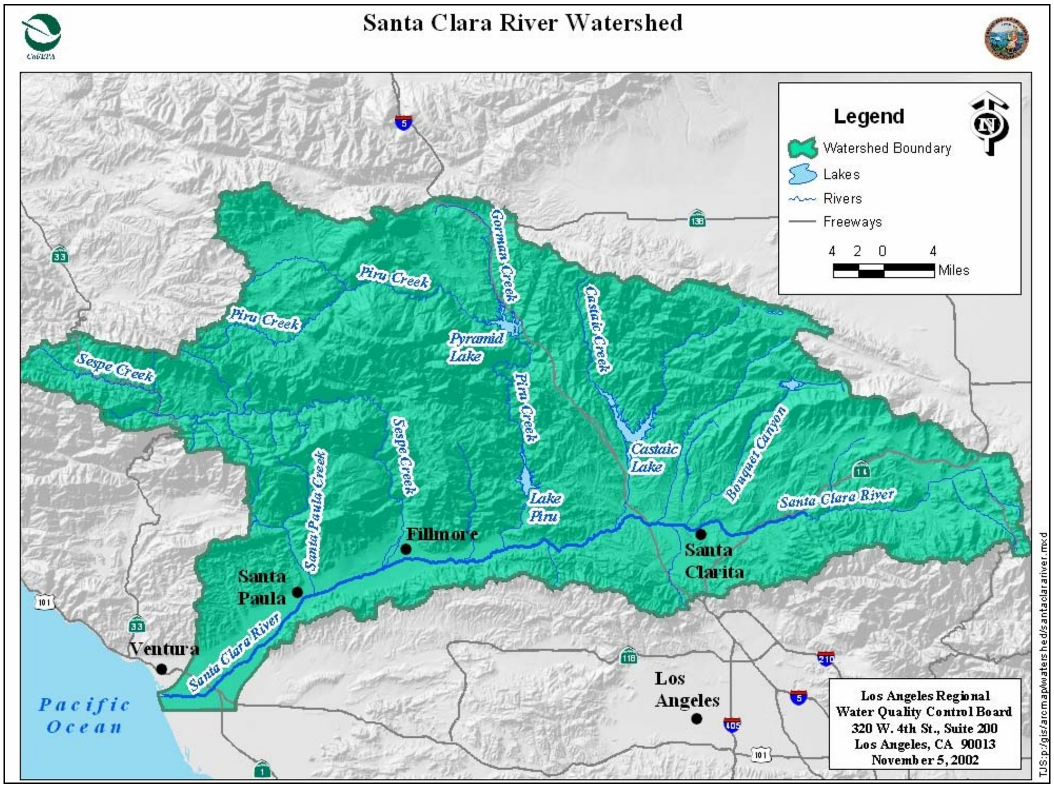
Figure A Santa Clara River Watershed



Source: Los Angeles Regional Water Quality Control Board

Box 19-2 Case Study 2: Integrated On-Farm Drainage Management — A Farm-level Solution to Problem Salinity

In the late 1990's, the 1,200-acre AndrewsAg farm in Kern County was a cotton and alfalfa operation. Drainage water from the farm was discharged to a 100-acre evaporation pond. Unfortunately, the high concentrations of salts and selenium in the pond posed a serious risk to wildlife. To develop a practical farming system that would eliminate the evaporation pond as the final disposal point for the drainage water, and therefore provide a safe environment for wildlife, AndrewsAg switched to the Integrated On-Farm Drainage Management (IFDM) farming system, which was first pioneered at Red Rock Ranch in Fresno County.

IFDM is an integrated agricultural water management system by which subsurface drainage water is applied sequentially to increasingly salt-tolerant crops. Drainage water from irrigating salt-sensitive crops can be reused at a given level of salinity to irrigate salt-tolerant crops. The number of steps comprising the reuse sequence can vary, as can the crops to which the drainage water is applied at each stage of the sequence. Once the drainage water becomes too salty to grow any crops, the remaining drainage effluent from the final stage in the sequence of reuse is evaporated in a solar evaporator, leaving crystallized salts behind. In the solar evaporator, the concentrated drainage water is distributed using timed sprinklers or other equipment that sets and adjusts the discharge rate so that water does not pond on the surface of the solar evaporator. The dry salt mixture may contain chemicals of commercial value that can be harvested.

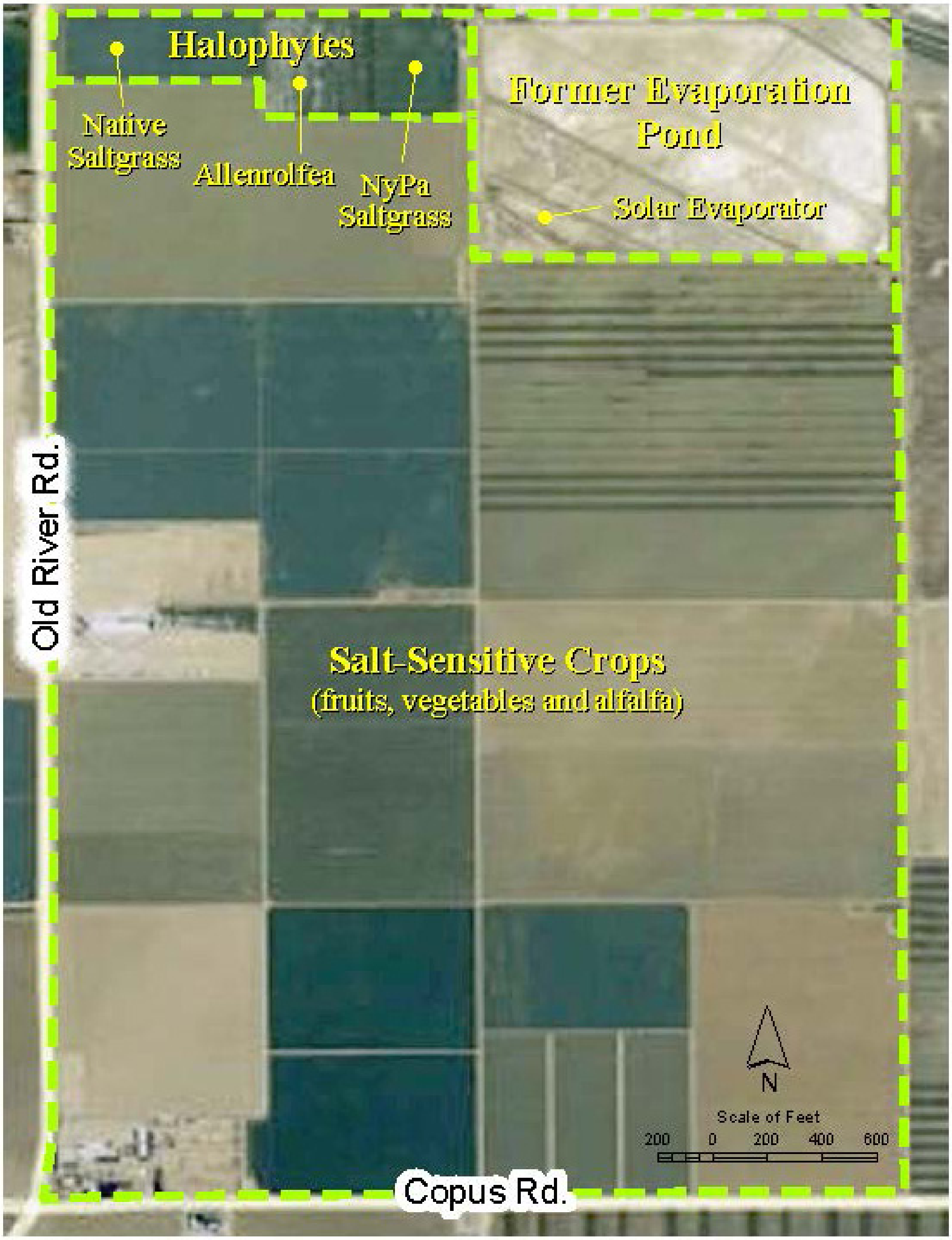
AndrewsAg has been using the IFDM system on 1,200 acres for about 10 years, and has successfully managed drainage water, salt, and selenium in an ecologically sound way to grow a variety of high-value crops. The AndrewsAg IFDM system starts with low salinity water to irrigate salt-sensitive, high-value fruit and vegetable crops and alfalfa. For many years, subsurface drainage water from this low-salinity zone was applied to salt-tolerant crops, such as cotton, and the subsurface drainage water collected from this first reuse was applied to a high-salinity zone of salt-loving plants called halophytes. Both applications reduce the volume of drainage water and take up the salt and selenium. Finally, drainage water from the high-salinity zone is evaporated by the solar evaporator. Most recently AndrewsAg installed a high efficiency drip irrigation system which eliminates the first reuse step on the IFDM system.

The photo illustrates the layout of the IFDM system on the AndrewsAg farm. Salt-tolerant crops (halophytes) are in the northwest corner. The solar evaporator is in the northeast corner within the area of the former evaporation pond, and only occupies 20% of the area within the former evaporation pond. Fruit and vegetable crops and alfalfa are grown on approximately 1,140 acres (95%), halophytes are grown on 40 acres (3.3%), and the solar evaporator occupies 20 acres (1.7%).

PLACEHOLDER Figure A AndrewsAg Integrated On-Farm Drainage Management System

[The draft figure follows this page.]

Figure A AndrewsAg Integrated On-Farm Drainage Management System



Source: Department of Water Resources

Box 19-3 Case Study 3: San Joaquin River Water Quality Improvement Project - A Regional Solution to Problem Salinity

The Grassland Drainage Area (GDA) is an agricultural region on the Westside of the San Joaquin Valley. The agricultural land is productive, but the soils contain high levels of naturally occurring salts and trace elements such as selenium and boron. The salts and trace elements are leached from the soil when the fields are irrigated and accumulate in the agricultural drainage water that is collected in drainage pipes commonly called tile drains. Farmers have installed tile drains in their fields to protect their crops from waterlogging conditions. Until the 1990s, drainage water from the GDA that contained high concentrations of selenium, salts, and other constituents that are harmful to fish and wildlife was discharged directly to waterways that delivered water to wetland areas.

In 1996, several irrigation and drainage districts formed the Grassland Area Farmers, a regional drainage entity comprised of approximately 97,000 acres of irrigated farmland. The Grassland Area Farmers were faced with the challenges to maintain agricultural production in a region with shallow groundwater and naturally-occurring salts, and to reduce and eventually eliminate all farm drainage discharge from the region.

The Grassland Bypass Project was initiated in 1998 to separate good-quality water upslope of the GDA from drainage water by consolidating subsurface drainage water from the GDA into a single channel (Grasslands Bypass Channel, constructed in 1996) into the San Luis Drain. The drainage water is discharged through the San Luis Drain to Mud Slough, approximately 8 miles upstream of the San Joaquin River.

To manage and reduce the drainage discharge to the San Joaquin River, Grassland Area Farmers are making irrigation and infrastructure improvements to reduce the amount of applied water. By pumping groundwater above the Corcoran clay layer and using that groundwater for irrigation, Grasslands Area Farmers are lowering the perched water table to reduce the amount of groundwater entering the subsurface drains. Finally, Grasslands Area Farmers are reusing drainage water by implementing a regional version of the Integrated On-Farm Drainage Management (IFDM) system on their 97,000 acres, where each phase of reuse significantly reduces the quantity of subsurface agricultural drainage water.

From 1997 to 2000, Grassland Area Farmers began recirculation projects where a portion of the drainage water is collected and re-circulated back into irrigation distribution systems and blended with fresh water for use on crops. In 2001, Grassland Area Farmers implemented the San Joaquin River Water Quality Improvement Project (SJRIP), an IFDM system. 4,000 acres were purchased for the reuse area, some salt-tolerant crops were planted in the winter of 2001, and distribution facilities were constructed that irrigated 1,821 acres with drainage water and/or blended water. Subsurface drainage systems were installed in 2002. Salt-tolerant crops, including Jose Tall Wheatgrass, Bermuda and fescue pasture, pistachio trees, and alfalfa were planted in the reuse area. The following year more subsurface drainage systems were added and halophytes were planted on 153 acres.

The Grassland Area Farmers continue to use and expand the SJRIP, and by 2010 the total acreage of the SJRIP had increased to more than 6,000 acres, with approximately 5,100 developed to salt-tolerant crops for drainage reuse. Approximately 12,400 acre-feet of drainage water was reused on the SJRIP in 2010.

From 1995 (before projects) to 2010, drainage water discharge volumes, as well as selenium, boron, and salt loads have been reduced significantly. More than 57,500 acre-feet of drainage water was discharged through drainage canals in 1995 before establishing the Grassland Bypass Project. By 2010, that amount of drainage water had been reduced to 14,400 acre-feet, a 75% reduction. During that period, the amounts of selenium, salt, and boron had dropped 87%, 72%, and 64% respectively.

The actions taken by the Grassland Area Farmers have led to significant selenium load reductions, and two water bodies (Salt Slough and the San Joaquin River below the Merced River) as well as over 90-miles of wetland water supply channels in the Grassland Watershed that were listed as impaired because of the high selenium levels have been de-listed by the State Water Resources Control Board. The U.S. EPA considers this project a “nonpoint source program success story.”

The drainage volumes and associated salts and trace elements are expected to continue to decrease as more reuse area is developed, the operational flexibility and efficiency of the SJRIP improves, more high-efficiency drip and micro-sprinkler irrigation systems are installed, and as new wells are installed to pump water from the perched water table and recycled to irrigate crops.

Although substantial progress has been made, additional work is required to achieve the ultimate goal of zero discharge. The final step for the remaining drainage water will be to collect the brine from the reuse area for further treatment and disposal by non-agricultural processes.

Reverse osmosis (RO) desalination has been tested on drainage water by the U.S. Bureau of Reclamation and University of California, Los Angeles. This process, where drainage water is forced through a membrane to separate contaminants from the water, produces one stream of very good quality water and a second stream of concentrated brine. There has been pilot testing of various innovative treatment technologies to remove selenium from the concentrated brine. For example, salts from the brine such as calcium sulfate (gypsum), sodium chloride, and sodium sulfate could be separated and recycled. In addition, the U. S. Bureau of Reclamation is building a pilot treatment facility on a portion of land in the San Joaquin River Water Quality Improvement Project. The pilot treatment facility is expected to be operational in 2013 and will test various drainage treatment processes.

PLACEHOLDER Figure A San Joaquin River Water Quality Improvement Project (SJRIP) Regional Water Reuse Areas

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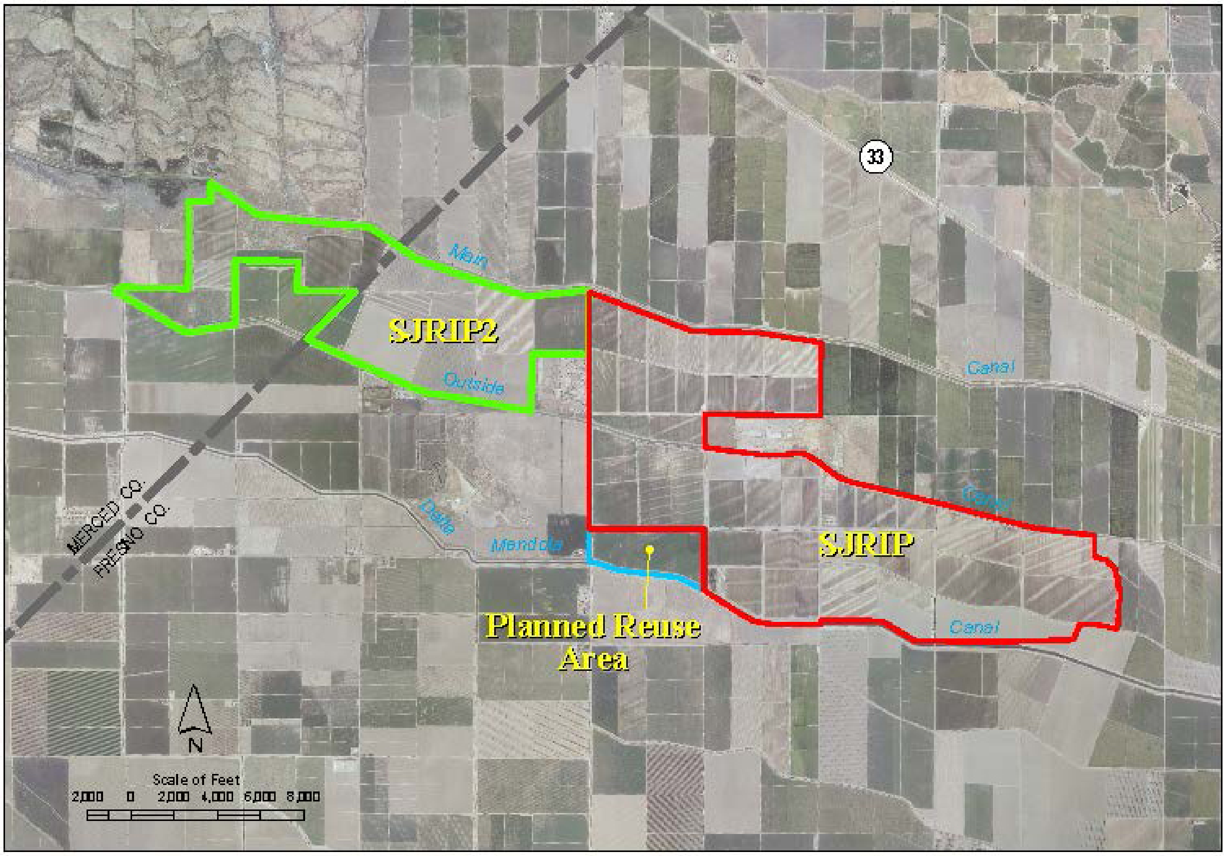
Figure A San Joaquin River Water Quality Improvement Project (SJRIP) Regional Water Reuse Areas



Source: Summers Engineering, Inc.

Box 19-4 Case Study 4: Salt Management in the Santa Ana Watershed Requires Regional Salt Disposal Options

> "The Inland Empire Brine Line has allowed us to use groundwater from salt-degraded aquifers and capacity in that line will be the limiting factor in our future groundwater recovery and recycling efforts."
>
> — Don Galliano, Board Member, Western Municipal Water District

Benefits of the regional brine line are:

- Allows the use of groundwater resources from aquifers with too much salt or other contaminant(s) for use.
- Protects and improves groundwater quality through salt and contaminant removal.
- Allows industry to take advantage of Inland Empire opportunities and meeting salt discharge standards for water used in industrial process.
- Orange County groundwater aquifers protected and do not require additional desalting.

Salt concentrations in the region's underground aquifers have increased over time as a result of historic agricultural and industrial practices and the use of high-salinity imported water. In some instances, high salt concentrations limit the potential to make use of local groundwater sources. For this reason, brackish groundwater desalination facilities have been constructed in the watershed to remove salt and provide needed drinking water sources, but desalination results in a concentrated stream of high-salinity brine that requires disposal outside of the watershed. Furthermore, the establishment of certain types of water-intensive industries, such as power plants, food processors, and technology businesses in the watershed, also requires a vehicle for the safe disposal of concentrated salt water that cannot go to sanitary sewers.

The Inland Empire Brine Line, also known as the Santa Ana River Interceptor (SARI) system, was constructed in phases over a period of 20 years, stemming from a vision of a salt-balanced watershed articulated in the early 1970s. The SARI is a complex system of 93 miles of pipelines that collects high-salinity flows throughout the watershed and conveys them to an Orange County Sanitation District treatment facility prior to discharge to the Pacific Ocean. Flows collected by the SARI could not go to local sanitary sewers and wastewater treatment plants due to their high salinity which adversely affects the ability to reclaim and reuse wastewater.

The construction of this important infrastructure was the result of a cooperative approach requiring coordination of several water agencies and a holistic integrated view of water management in the watershed. This multi-agency participation was essential for the construction of an impressive system that could not have been implemented by a single agency.

The Inland Empire Brine Line partnering agencies are:

- San Bernardino Valley Municipal Water District.
- Eastern Municipal Water District.
- Western Muncipal Water District.
- Inland Empire Utilities Agency.
- Orange County Sanitation District.

Using a novel partnership model, the SARI was constructed with loans that were repaid using revenue generated from the sale of capacity in the system to those anticipating desalting needs. Operation and maintenance continues to be funded with revenue and capital reserves generated from rates. In addition, capital-intensive improvements may be funded through debt financing.

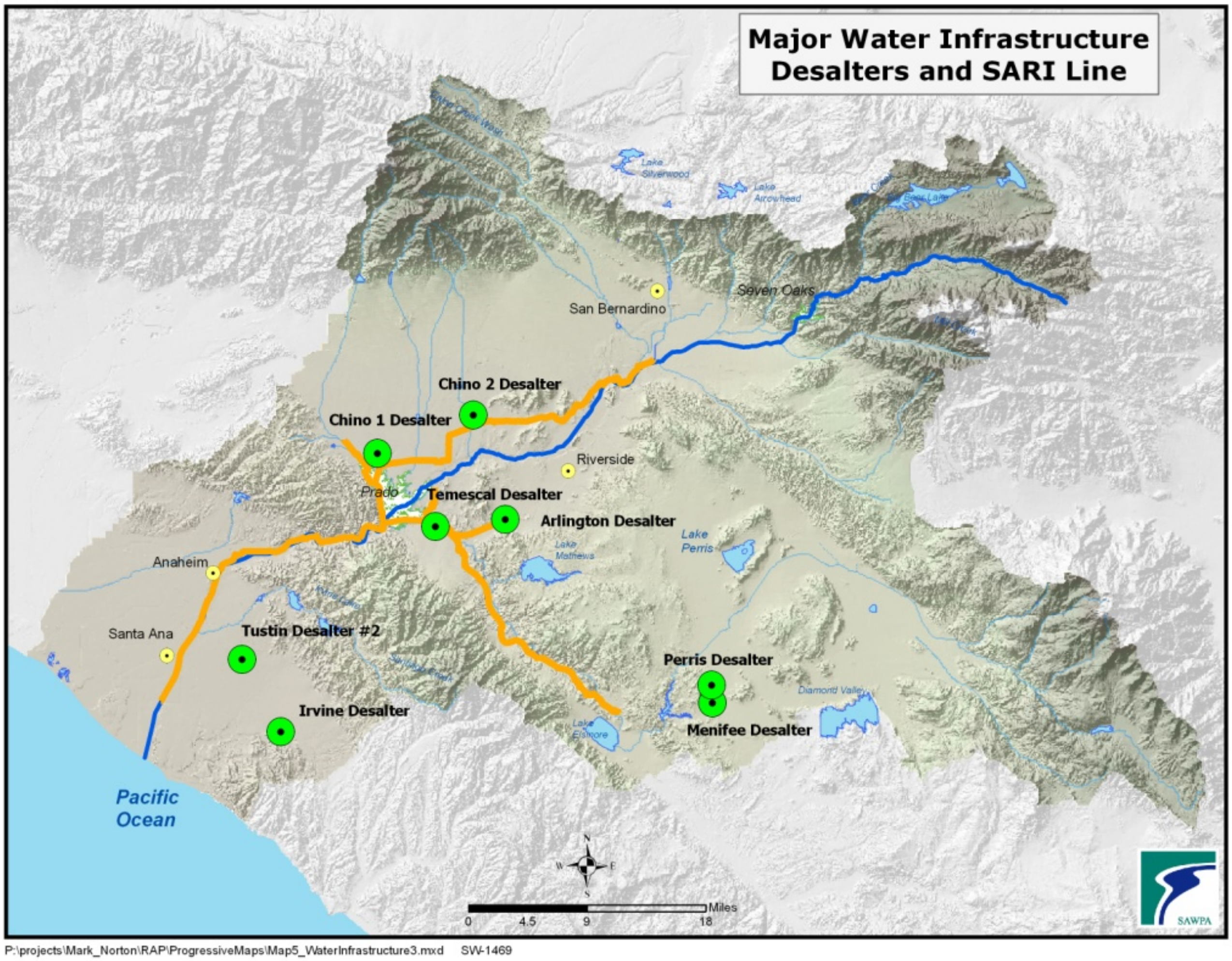
There are clear cost advantages to using brine line disposal options within the watershed as opposed to trucking the brine outside of the region. Based on 1-million gallons of low biochemical oxygen demand (BOD)/total suspended solids (TSS) brine waste for the Inland Empire region, disposal costs for direct connection to the SARI, truck dump to the SARI, and transport out of the basin are documented at $2,000, $50,000, and $250,000, respectively (Santa Ana Watershed Project Authority 2012).

Summarizing the project: there are clean groundwater basins, additional available local water supplies, and benefits to industry.

PLACEHOLDER Figure A Major Water Infrastructure Desalters and SARI Line

[The draft figure follows this page.]

Figure A Major Water Infrastructure Desalters and SARI Line



Source: Santa Ana Watershed Project Authority

Box 19-5 Case Study 5: Central Valley Salinity Alternatives for Long-term Sustainability (CV-SALTS)

Nowhere in California is salinity a more significant threat to sustainability than in the Central Valley. Salinity threatens the long-term reliability of water supplies and community water quality as groundwater basins are impacted and farmland goes out of production.

In 2007, area stakeholders, the Central Valley Regional Water Quality Control Board, and State Water Resources Control Board initiated a unique collaborative salinity management effort partially modeled on the Santa Ana Watershed approach described in Case Study 4, Box 19-4 only on a much grander scale.

The Central Valley region is comprised of three major basins and covers a 60,000 square mile area that extends from the Tehachapi Mountains in the south to the Oregon border in the north. The Central Valley Salinity Alternatives for Long-term Sustainability (CV-SALTS) is an initiative that addresses salinity throughout the region and the Delta in a comprehensive, consistent, and sustainable manner through the development of a Salt and Nitrate Management Plan for the Central Valley region. Similar to the Santa Ana Watershed Project Authority (SAWPA), CV-SALTS encourages stakeholder-initiated actions and leadership that can accomplish management that the Regional Water Quality Control Boards are unable to require, but which will make it possible to achieve and maintain sustainable salinity management in the region.

Several organizations are currently active in the CV-SALTS initiative. The Water Boards provided initial support and continue to play key advisory roles. The Central Valley Salinity Coalition, a strong initial and ongoing funder of the CV-SALTS initiative, includes members from statewide and regional associations, agricultural coalitions, cities, counties, and special districts representing a majority of the Central Valley. The Executive Committee charged with the governance of this broad-reaching initiative has representatives from the Central Valley Salinity Coalition as well as representatives from state and federal agencies, local governments, and from nongovernment, environmental justice, and industry organizations. The Technical Advisory Committee includes top researchers and consultants in the field to review scientific and technical issues and economics. Other committees made up of stakeholders serve as technical reviewers of management practices, conduct outreach, review economic and technical studies, and related efforts.

These efforts will develop the science and policy required to review and update the Water Quality Control Plans for the Sacramento and San Joaquin River basins, the Tulare Lake basin, and the San Francisco Bay/Sacramento - San Joaquin Delta Estuary.

More information is available on the CV-SALTS committees and the Central Valley Salinity Coalition at http://cvsalinity.org/.